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American Association of Petroleum Geologists

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BULLETIN
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AMERICAN ASSOCIATION OF
PETROLEUM GEOLOGISTS

JANUARY, 1940

WEST TEXAS-NEW MEXICO SYMPOSIUM: PART I

EDITORIAL INTRODUCTION

RONALD K. DEFORD[1] AND E. RUSSELL LLOYD[2]
Midland, Texas

ABSTRACT

Besides other introductory information, this paper takes up problems of nomenclature. It clarifies the meaning of the term *Carlsbad limestone*, discusses the advantages and disadvantages of the use of the term *Whitehorse* in West Texas and New Mexico, and mentions other problems.

The West Texas-New Mexico symposium is composed largely of papers read at the mid-year meeting of the American Association of Petroleum Geologists in El Paso, Texas, September 29–30, 1938.

INDEX MAP

A feature of the printed program of the mid-year meeting was the index map (Fig. 1). The local details of this map were not a subject of unanimous agreement even at El Paso, and since then more than a year has elapsed. Knowledge, particularly of subsurface details, has increased. Nevertheless the map is still useful as an index to regional structure and to individual papers, and as such it is reprinted here without revision.

SYMPOSIUM: PART I

The technical program of the mid-year meeting was divided into three parts: the introductory papers, the pre-Permian papers, and papers on the Permian.

Part I of the symposium consists of introductory and pre-Permian papers and thus serves as an introduction to Part II, which will deal mainly with Permian rocks of the West Texas-New Mexico Permian basin. Not all the introductory and pre-Permian papers of the pro-

[1] Argo Oil Corporation.

[2] Consulting geologist.

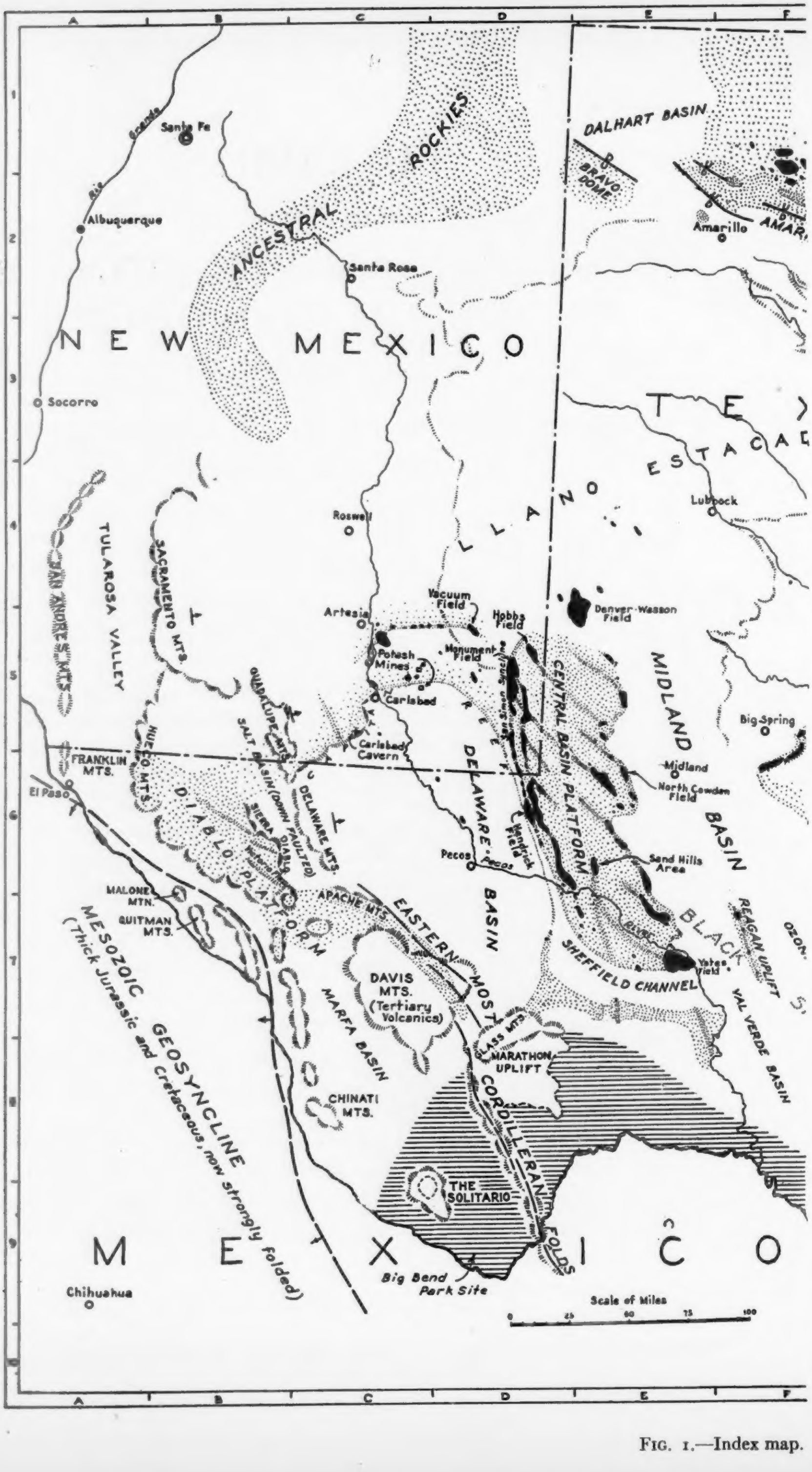
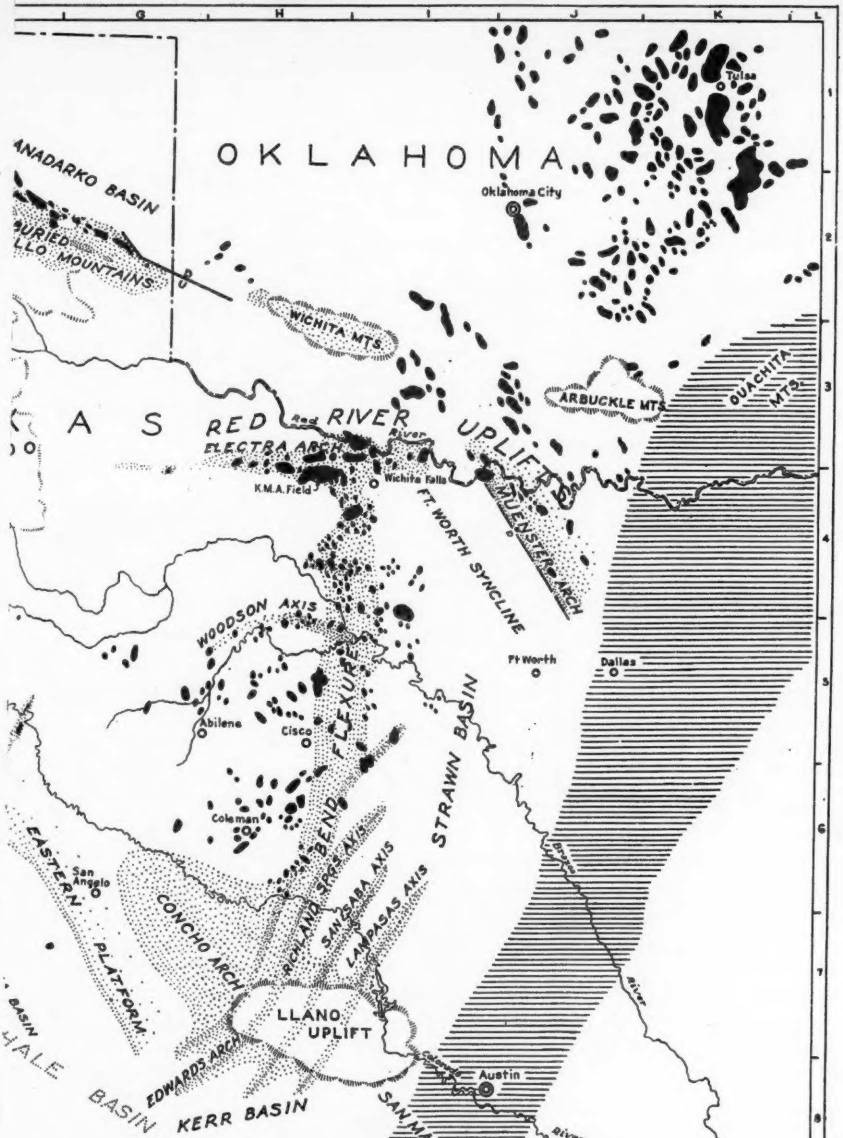


FIG. 1.—Index map.



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REGIONAL STRUCTURE AND INDIVIDUAL PAPERS
MIDYEAR MEETING
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
EL PASO, TEXAS ~ SEPTEMBER 29 & 30, 1938

ap.

COLUMN		1	2	3	4	5
		GLASS MOUNTAINS	DELAWARE BASIN	SIERRA DIABLO GUADALUPE MOUNTAINS HENDRICK FIELD	NEW MEXICO AND MIDLAND BASIN	EAST SIDE OUTCROPS
TERTIARY					Ogallala	Ogallala
CRETACEOUS		Comanche			Comanche	Comanche
TRIASSIC		Bissett	Chinle Santa Rosa Tecovas	Chinle Santa Rosa Tecovas	Chinle Santa Rosa Tecovas	Dockum
PERMIAN	Ochoa	Tessey	Dewey Lake Rustler Upper Castile (Salado) Lower Castile (Castile)	Dewey Lake Rustler Upper Castile (Salado)	Dewey Lake Rustler Upper Castile (Salado)	
	Guadalupe	Gilliam: Vidrio Word	Delaware Mtn.: Bell Canyon Cherry Canyon Brushy Canyon	Capitan Cherry Canyon Brushy Canyon	Carlsbad: Tansill Yates Seven Rivers Queen Grayburg Whitehorse ?	Whitehorse
	Leonard	Leonard (Hess)	Bone Spring	Bone Spring (Victorio Peak is top gray ls. phase)	NEW MEXICO: San Andres (Glorieta is basal ss. phase) Yeso MIDLAND BASIN: San Andres Clear Fork "Wichita"	El Reno: Dog Creek Blaine Flower-pot San Angelo Clear Fork Lueders Clyde Belle Plains
	Wc.	Wolfcamp	Wolfcamp	Hueco	Abo (New Mexico); Wolfcamp (Midland Basin)	Wolfcamp
PENNSYLVANIAN		MARATHON REGION	EL PASO REGION	CENTRAL BASIN PLATFORM AND MIDLAND BASIN		
		Gaptank Haymond Dimple Tesnus	Magdalena	Pennsylvanian		Cisco Canyon Strawn Lampasas Morrow
MISSISSIPPIAN			Helms Lake Valley	Mississippian		Barnett Chappel
DEVONIAN		Caballos	Percha Canutillo	Devonian		
SILURIAN			Fusselman	Silurian		
ORDOVICIAN		Maravillas Woods Hollow Fort Pena Alsate Marathon	Montoya El Paso Bliss	Upper Ordovician Simpson Ellenburger		Ellenburger
CAMBRIAN		Dagger Flat	Van Horn			San Saba Wilberns Cap Mountain Hickory
PRE-CAMBRIAN			Hazel Allamoore Carrizo Mountain	Pre-Cambrian		Packsaddle Valley Spring

FIG. 2.—Correlation chart.

gram are included. The order of papers is somewhat different, and among them are Philip B. King's paper on the older rocks of the Van Horn region and John Emery Adams' account of the structural development of the Yates area, which were not a part of the El Paso program.

The symposium begins with the three large cross sections by Fritz and FitzGerald, Woods, and Dickey, which give a general view of the stratigraphy of the region. They show principally the Permian rocks but also some older and younger beds. Following them and rounding out the introductory picture of the "basin" is the cross section of Page and Adams, which accompanies their paper, "Stratigraphy, Eastern Midland Basin, Texas."

Then comes Cheney's "Geology of North-Central Texas," devoted chiefly to the older rocks in the outcrops and subsurface of the east side of the West Texas Permian basin. Although this paper is fairly brief, it deals with an area nearly as large as the state of Pennsylvania. It makes fundamental changes in the classification of Pennsylvanian and early Permian rocks and is thus so loaded with information in a condensed form that the text can be readily followed only by repeated reference to the illustrations. Cheney proposes also a number of new series, group, and formation names.

From north-central Texas the symposium moves again westward to the Central Basin platform in the middle of the Permian basin. Here, Powers discusses the pre-Permian and older Permian rocks and the oil pools of the Sand Hills area, and Adams gives a fascinating account of the Permian and post-Permian structural history of the Yates area.

The next westward step is to Van Horn, where King reclassifies the older rocks; thence to El Paso, where Nelson describes the Franklin Mountain section; thence to New Mexico, where Needham, by means of paleontology, correlates the Pennsylvanian rocks with distant standard sections. Last, Skinner redescribes the section in the Chinati Mountains of southwestern trans-Pecos Texas, where a rather full representation of Pennsylvanian and Permian rocks crops out.

CORRELATION CHART

The printed program at El Paso also contained a five-column correlation chart. The same five-column scheme is retained in Figure 2, but the correlations and nomenclature are brought up to date.

The purpose of the chart is to show equivalency. It contains system, series, group, and formation names. These are listed in correlative position, each as a name *per se*, without any sustained attempt to indicate the relative rank of the rock units they represent. The

chart has no relation whatever to thickness. Unconformities are shown with wavy lines which represent the absence of formations. Undoubtedly more hiatuses exist than are so shown.

PRE-PERMIAN NOMENCLATURE

Philip B. King's new classification of the pre-Cambrian rocks in the Van Horn region is shown in column 2 of the correlation chart under the heading "El Paso Region." The questioned arrow indicates the doubtful Cambrian or pre-Cambrian age of the Van Horn sandstone. The Bliss sandstone is shown as Lower Ordovician according to the new classification of Philip B. King and Josiah Bridge of the United States Geological Survey. L. A. Nelson does not agree with this classification. Column 2 also shows Nelson's new Middle Devonian Canutillo formation.

In column 5, Cheney's reclassification of the Pennsylvanian system of north-central Texas is shown. He proposes to divide the Pennsylvanian into five sedimentary series named, in ascending order, Morrow, Lampasas, Strawn, Canyon, and Cisco. In making this classification Cheney cuts the old Bend group in two, adds a little basal "Strawn" to the upper subdivision, and raises both subdivisions to series rank, remarking, however, that "the term *group* has such a broad meaning and wide application without regard to series boundaries that continued use, when needed, of the term *Bend group* does not appear inconsistent . . . " For the lower subdivision he introduces the name *Morrow series* from Oklahoma; for the upper subdivision he proposes the new name *Lampasas series.*

Cheney raises the well known Strawn, Canyon, and Cisco groups to series rank. He redefines the Strawn and Canyon by lowering the Strawn-Canyon boundary and restricts the Cisco by placing its top at a horizon 50–100 feet below the Saddle Creek limestone of previous nomenclature. The name *Harpersville* is abandoned. The top of his Cisco series thus coincides with the top of his Thrifty group (expanded) and the base of his Pueblo group (expanded); in other words, it is designed to coincide with the Pennsylvanian-Permian boundary.

The editors believe that Cheney's reclassification of the Pennsylvanian and Lower Permian of north-central Texas will be generally accepted as the standard section of that area.

PERMIAN NOMENCLATURE

Four Permian series.—At the left side of the correlation chart (Fig. 2) is shown the proposed division of the Permian system into

four series[3] named, in ascending order, Wolfcamp, Leonard, Guadalupe, and Ochoa.

Wichita group.—In north-central Texas Cheney proposes to abandon the Wichita group and to raise the Belle Plains, Clyde, and Lueders formations to group rank. His new classification is shown in column 5 of the correlation chart. Dickey, however, being unable to distinguish Belle Plains, Clyde, and Lueders in the subsurface of West Texas, proposes to retain the name *Wichita group* (restricted) for pre-Clear Fork beds of Leonard age.

San Andres.—In contrast to the correlation chart in the El Paso program, Figure 2 shows the San Andres as of Leonard age. This indicates a veering in the consensus in the year that has elapsed since the meeting, but it is not concurred in by some geologists, notably Frank E. Lewis. The correlation is not considered as finally settled. It is very likely that careful field work in the northern Guadalupe Mountains would solve the problem. The detailed field studies of Philip B. King and others in the southern Guadalupe Mountains should be extended northward into New Mexico.

The Oklahoma-Kansas terms *Flower-pot, Blaine,* and *Dog Creek* are in common use, as shown in column 5, for subdivisions of the San Andres in the east-side outcrops. The San Andres has been called a formation in New Mexico, but in view of these formational subdivisions which are shown on Dickey's, Page and Adams', and Cheney's cross sections, it is considered a group in this symposium.

The name *San Andres* comes from a type locality[4] in the north end of the San Andres Mountains of New Mexico, where the top of the San Andres group is not defined by an overlying formation. The test of the accuracy and desirability of applying the name San Andres as it is applied in this symposium lies in the projected stratigraphic research to determine the relation of the 1,200 feet of beds so called to the Leonard and Guadalupe series of the Delaware basin. Proof that part of our "San Andres" is Leonard and part Guadalupe, or other contingencies, could require a modification of the present usage.

El Reno group.—In Oklahoma the term *El Reno group* is in use. As the "east-side outcrops" in west-central Texas (Fig. 2, col. 5) resemble the Oklahoma section but are quite different from the typical San

[3] John Emery Adams, M. G. Cheney, Ronald K. DeFord, Robert I. Dickey, Carl O. Dunbar, John M. Hills, Robert E. King, E. Russell Lloyd, A. K. Miller, and C. E. Needham, "Standard Permian Section of North America," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 11 (November, 1939), pp. 1673–81.

[4] Willis T. Lee and George H. Girty, "The Manzano Group of the Rio Grande Valley, New Mexico," *U. S. Geol. Survey Bull. 389* (1909), pp. 12–13.

Andres limestone, Cheney, with reason, prefers the term *El Reno group* for his region. Frank E. Lewis also traces the El Reno group southward from Oklahoma and correlates it with the San Andres.

Robert Roth in a personal communication to M. G. Cheney (August 26, 1939) wrote: "The El Reno is an Oklahoma facies name for pre-Custer Double Mountain beds. Suggest that some more appropriate name be used." This statement seems to imply that *El Reno* refers by definition only to the Chickasha-Duncan coarsely clastic, cross-bedded, deltaic facies, but Henry Schweer and Hastings Moore, who took part in choosing the name, state[5] explicitly that it applies also and equally to the "even-bedded" facies, including the Flowerpot, Blaine, and Dog Creek formations. Since this sequence is similar to that in west-central Texas, Roth's suggestion seems too absolute.

H. C. Fountain,[6] presumably rejecting *El Reno* for similar reasons, plans to propose instead the name *Pease River group*.

Delaware Mountain group.—In the Delaware basin the Guadalupe series is represented by a sandstone facies called the Delaware Mountain sandstone, now recognized as a sedimentary *group*. Its three subdivisions, heretofore called simply "lower," "middle," and "upper," will be defined by type localities and designated by the formational names *Brushy Canyon*, *Cherry Canyon*, and *Bell Canyon*, respectively, in Philip B. King's forthcoming paper on the West Texas Permian. With King's permission these names are included in columns 2 and 3 of the correlation chart (Fig. 2).

Whitehorse group.—According to prevalent usage in Oklahoma, where the Whitehorse was named, the Whitehorse group comprises, in ascending order, the Marlow, Rush Springs, and Cloud Chief formations. The Cloud Chief is overlain in places by the Day Creek dolomite.

For more than 10 years—almost since the beginning of careful study of the West Texas-New Mexico Permian basin—the term *Whitehorse* has been applied to the beds between the Upper Castile ("main salt") and the San Andres. Frank E. Lewis, in his stereograms, applies Oklahoma names to West Texas approximately as follows: Marlow to the lowest formation (Grayburg) of the West Texas "Whitehorse"; Rush Springs to the Queen sand of this symposium; Cloud Chief to the Seven Rivers formation of this symposium. Most West Texas geologists concur in these *approximate* cor-

[5] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 12 (December, 1937), pp. 1554–56.

[6] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 5 (May, 1939), p. 764. See also road log of North Texas Geological Society field trip, April 28–29, 1939, which contains illustrations showing detailed correlation with the Oklahoma section.

relations, but H. L. Griley,[7] who has studied the Permian of Oklahoma in detail, holds to the old correlation of Cloud Chief with Upper Castile.

Thus the West Texas term *Whitehorse*, if it be otherwise suitable, has the advantage of long-established usage. It also has the advantage of applying a single name to beds of the same age over a region at least 500 miles wide.

According to the viewpoint of some geologists the term has disadvantages that outweigh the advantages. Certain symposium papers indicate that the Yates and Tansill formations of the top part of the West Texas "Whitehorse" group pinch out in the subsurface before they reach the east-side outcrops. According to this interpretation the Seven Rivers formation is approximately equivalent to the Cloud Chief formation of Oklahoma, and Yates and Tansill equivalents are not present in the typical Whitehorse of Oklahoma. It is also possible that the oldest "Whitehorse" beds of West Texas and New Mexico are represented by hiatus in Oklahoma. Such evidence is used by Cordry[8] and others as argument against the continued use of *Whitehorse* in our region.

Among possible alternatives the suggested term *Capitan* is unsuitable, not only because it is probably desirable to continue to limit it to the massive limestone facies to which it was originally applied, but also because the oldest part of the present "Whitehorse" is equivalent to beds that underlie the Capitan at its type locality. Robert Roth's *Custer* in Oklahoma and Kansas includes the Quartermaster as well as the Whitehorse. It is unsuitable as a substitute for "Whitehorse" in West Texas and New Mexico not only because of a present trend of opinion that places the Quartermaster tentatively in the Triassic but also because Roth insists that Custer includes Upper Castile.

Lang's term Chalk Bluff[9] is a suitable New Mexico synonym for "Whitehorse," if one is needed.

In the present symposium the Whitehorse group of West Texas and New Mexico is divided from the base upward into five formations: Grayburg, Queen, Seven Rivers, Yates, and Tansill. *Grayburg* and *Tansill* are new names; the Tansill will be defined in Part II of the West Texas-New Mexico symposium.

[7] Personal communications, 1939.

[8] See footnote 6, Elliot H. Powers, "Sand Hills Area, Crane County, Texas," in this symposium.

[9] Walter B. Lang, "The Permian Formations of the Pecos Valley of New Mexico and Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 7 (July, 1937), p. 856.

The lowest formation of the Whitehorse group, the Grayburg, is defined by Dickey in his paper herewith. The proposal of this name from a subsurface type locality may be considered a necessary and practical step taken for the sake of definiteness in immediate stratigraphic studies. No doubt a fossiliferous section of equivalent beds exists in the Guadalupe Mountains, which, when it is thoroughly studied and described, may displace the Grayburg type locality. Lang's[10] "Dog Canyon" formation includes parts of this section, but it is so inadequately defined and so loosely tied in paleontologically and stratigraphically that it is hardly suitable for present needs. It might properly be redefined, and the symposium authors, anticipating its redefinition, might have used it instead of Grayburg but for one other fact: the "Dog Canyon" has been continually confused in oral geologic discussions with the Dog Creek, which immediately underlies the Grayburg and thus is in close juxtaposition to the "Dog Canyon." The confusions are due to slips of the tongue, but they are real confusions nevertheless, and West Texas geologists hope to end their frequent recurrence by abandoning the term *Dog Canyon*.

The five formations of the Whitehorse group grade southwestward into beds of Guadalupe age in the Delaware basin. Where such typical Whitehorse evaporites and clastics as anhydrite, red sand, salt, and thin limestones approach the margin of the Delaware basin they grade into thin-bedded limestones that retain a sufficient number of the sandstone members to permit the separate formations to be distinguished even within the thin-bedded limestone facies. These thin-bedded Tansill, Yates, Seven Rivers, and possibly Queen limestones grade into massive reef limestone within which the separate formations are not distinguishable.

Carlsbad limestone.—For 15 years or more, since the first oil geologists spoke of the outcrops near Carlsbad as "Carlsbad limestone," the top of the Carlsbad has never been in question, but even after its first definition in the literature the position of its base was uncertain, and the proper usage of the term has been a subject of debate. The authors of this editorial introduction believe that the question can now be settled.

In an abstract prepared for the program of the El Paso mid-year meeting DeFord, Riggs, and Wills[11] proposed to restrict the term *Carlsbad* to post-Yates beds—that is, to the beds now called Tansill.

[10] *Op. cit.*, p. 858.

[11] Ronald K. DeFord, Geo. D. Riggs, and Neil H. Wills, "Surface and Subsurface Formations, Eddy County, New Mexico" (abstract), *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 12 (December, 1938), pp. 1706–07.

Objection to this proposal was made by Walter B. Lang and Philip B. King of the United States Geological Survey. In conferences subsequent to the meeting attended by Lang, King, DeFord, and a representative group of West Texas geologists, it was decided to adopt Lang and King's usage of "Carlsbad," as set forth in the next paragraph.

Capitan and *Carlsbad* are names of different facies of equivalent beds. The Capitan limestone is a massive reef limestone, which grades basinward into upper Delaware Mountain sandstone (Bell Canyon) and lagoonward into Carlsbad limestone. The Carlsbad is thus the thin-bedded lagoonal limestone (with some interbedded sandstone) of Capitan age. Thin-bedded limestones older than Capitan are by definition not Carlsbad.

The Carlsbad includes the Tansill, Yates, and Seven Rivers formations and possibly some older beds. The names *Tansill*, *Yates*, and *Seven Rivers*, however, apply to formations that extend into the area of saline residues 100 or more miles beyond the limits of the Carlsbad, which is a thin-bedded *limestone* facies belonging only to that part of the lagoon immediately adjacent to the Capitan reef.

In the Glass Mountains (Fig. 2, col. 1) the thin-bedded Gilliam has much the same relation to the massive Vidrio that the Carlsbad has to the Capitan in the Guadalupe Mountains.

Salado and Castile.—In the subsurface of the Delaware basin a thick section of saline residues lies between the top of the Delaware Mountain sandstone and the base of the Rustler formation. In 1935 Lang,[12] dividing this section into two parts, proposed to restrict the term *Castile* to the lower part and to name the upper part *Salado*. Because his horizon of division was far above the one in common use in West Texas and New Mexico, his proposed terms failed to replace the *Lower Castile* and *Upper Castile* of the subsurface geologists. In a recent note,[13] Lang has so redefined his Salado formation that it is a practical equivalent of the "Upper Castile," and it is likely that his usage of Salado and Castile will prevail. His redefinition came too late to affect the present symposium, which follows the older nomenclature.

SYSTEMIC BOUNDARIES

Philip B. King's paper redefines the base of the Ordovician in the Van Horn region.

[12] Walter B. Lang, "Upper Permian Formation of Delaware Basin of Texas and New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 2 (February, 1935), pp. 262–70.

[13] *Idem*, "Salado Formation of the Permian Basin," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 10 (October, 1939), pp. 1569–72.

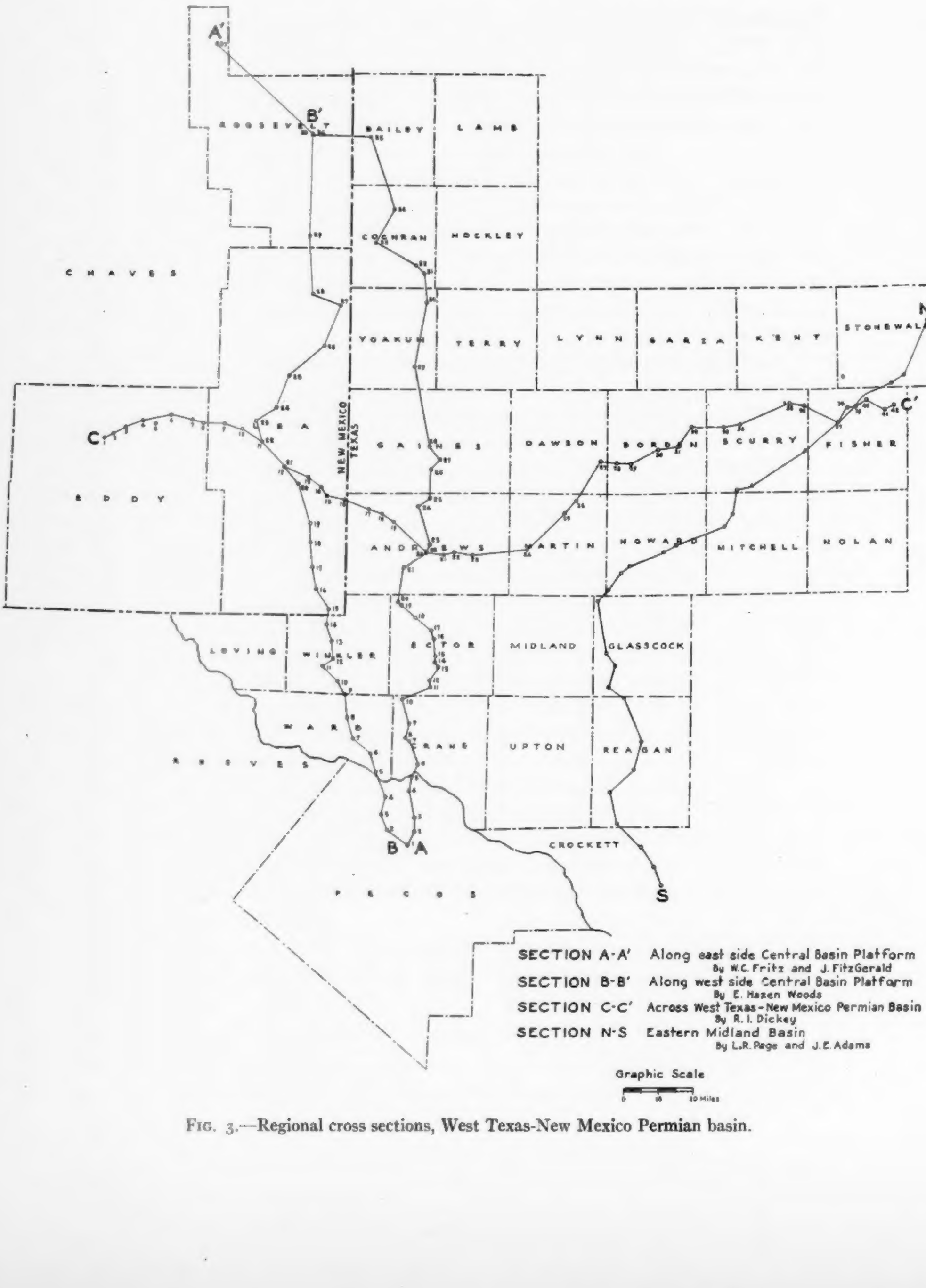

FIG. 3.—Regional cross sections, West Texas-New Mexico Permian basin.

Elliot H. Power's paper illustrates the marked unconformity at the base of the Permian in West Texas. M. G. Cheney redefines the Pennsylvanian-Permian boundary in north-central Texas to bring it in line with the commonly accepted horizon in Oklahoma, Kansas, and elsewhere. Paleontologically this horizon is the base of the *Pseudoschwagerina* zone, and stratigraphically it is the base of the Wolfcamp series. Cheney reclassifies the rocks of his region to fit the revised boundary. Needham gives data relative to the position of the same horizon in New Mexico, and Skinner, relative to its approximate position in the Chinati Mountains of trans-Pecos Texas.

Page and Adams' proposal to separate the post-Rustler pre-Santa Rosa redbeds into two formations—the newly named Permian Dewey Lake and the Triassic Tecovas—sheds new light on the Paleozoic-Mesozoic boundary in West Texas and New Mexico.

LEWIS STEREOGRAMS[14]

In 1938 Frank E. Lewis drew a series of colored stereograms to show his interpretation of the correlation of the upper Permian sedimentary rocks of West Texas and New Mexico. On the basis of this work he prepared a paper[15] for the mid-year meeting in El Paso but was called away to Kentucky and was unable to present his paper in person. During his continued absence his stereograms were re-drafted in black and white by W. M. Osborn without the benefit of Lewis' supervision. About the time the drafting was complete, Lewis returned to Midland, Texas, and approved the work as an essentially correct representation of his original work in color.

In several respects Lewis' correlations are radically different from the correlations followed by the authors of this symposium. That is one reason for presenting his stereograms at this time as an independent, dissenting interpretation. Discussion of details will be reserved until the publication of Lewis' paper on which he has resumed work since his return to Midland.

Another important aspect of Lewis' stereograms is that they boldly indicate a clear-cut tie between West Texas and the standard section of Oklahoma.

[14] NOTICE—These stereograms may be obtained on blue-line paper prints in 3 sheets approximately 72×42 inches, 48×40 inches and 32×20 inches, respectively (vertical scale, 1 inch = 1,000 feet), if order is sent promptly to A.A.P.G. headquarters, Box 979, Tulsa, Oklahoma. Price per set of 3, folded in mailing envelope, postpaid: to A.A.P.G. members and associates, colleges, and libraries, $3.35; to others, $4.25. On order of 100 or more, 10 per cent discount.

[15] Frank E. Lewis, "Stratigraphy of the Upper and Middle Permian of West Texas and Southeast New Mexico" (abstract), *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 12 (December, 1938), pp. 1710–11.

REGIONAL CROSS SECTIONS

Three large cross sections by Fritz and FitzGerald, Woods, and Dickey were exhibited at the El Paso mid-year meeting. They served as an introduction to and a guide for reference during the program. They are the subject of the first three papers of this symposium.

Figure 3 shows the location of these three cross sections and of a fourth by Page and Adams.

Cheney's cross sections are not shown on Figure 3. His longest section crosses the south part of the region shown on Figure 3 and continues eastward; it extends from the Marathon uplift (Fig. 1, co-ord. D-8) to Mineral Wells (co-ord. I-5). A south-north cross section extends from the Edwards arch (co-ord. G-8) to the Electra arch (co-ord. H-3). Another crosses the Llano uplift, extending from Uvalde County (co-ord. H-9) to Mills County (co-ord. I-7). Still others deal exclusively with the older rocks in parts of Cheney's region.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 1 (JANUARY, 1940), PP. 15-28, 1 FIG.

SOUTH-NORTH CROSS SECTION FROM PECOS COUNTY THROUGH ECTOR COUNTY, TEXAS, TO ROOSEVELT COUNTY, NEW MEXICO[1]

W. C. FRITZ[2] AND JAMES FITZGERALD, JR.[2]
Midland, Texas

ABSTRACT

The section from Shell-Kirby University No. 1 in central Pecos County, Texas, to Franklin Gephart No. 1 in northern Roosevelt County, New Mexico, extends generally along the eastern part of the Central Basin platform. It traverses most of the Upper Castile basin of deposition and shows its northern limit. Through Crane, Ector, and Andrews counties, the cross section is along the strike of the beds of the Whitehorse group. It shows the progressively increasing depth of the porous and producing zones from the Whitehorse group into the San Andres group, although the only oil wells shown on the section are producing from the San Andres or older beds. Some idea of the magnitude of the unconformity at the base of the Permian is indicated in the first ten wells in the section. The suspected relationship of the Glorieta (base of San Andres group) with the undifferentiated Permian of the southern part of the Central Basin platform is also shown.

ACKNOWLEDGMENTS

The writers are indebted to the Skelly Oil Company and its chief geologist, J. E. Morero, for permission to use the data of this company in the preparation of this paper.

The writers also wish to express their appreciation for the assistance and suggestions offered by E. Russell Lloyd and Ronald K. DeFord.

INTRODUCTION

The Central Basin platform is the most important feature of the West Texas-New Mexico Permian basin, because of the prolific production from its fields to date, 672,573,679 barrels to August 1, 1938, and in addition its sediments exhibit the most interesting geologic phenomena of the Mid-Continent region. Accordingly, the writers wish to present this cross section, which is drawn from south to north along the eastern side of the platform. (See Fig. 3, Editorial Introduction.)

Several excellent cross sections have been published in recent years covering the Central Basin platform.[3] The classics of Cartwright,[4]

[1] Read before the Association at El Paso, September 29, 1938. Manuscript received, August 11, 1939.

[2] Skelly Oil Company.

[3] Common preference of geologists in the area, although referred to by E. H. Sellards as "Pecos Uplift," in "Structural Map of Texas," 1936.

[4] Lon D. Cartwright, Jr., "Transverse Section of Permian Basin, West Texas and Southeast New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 8 (August, 1930), pp. 969-81.

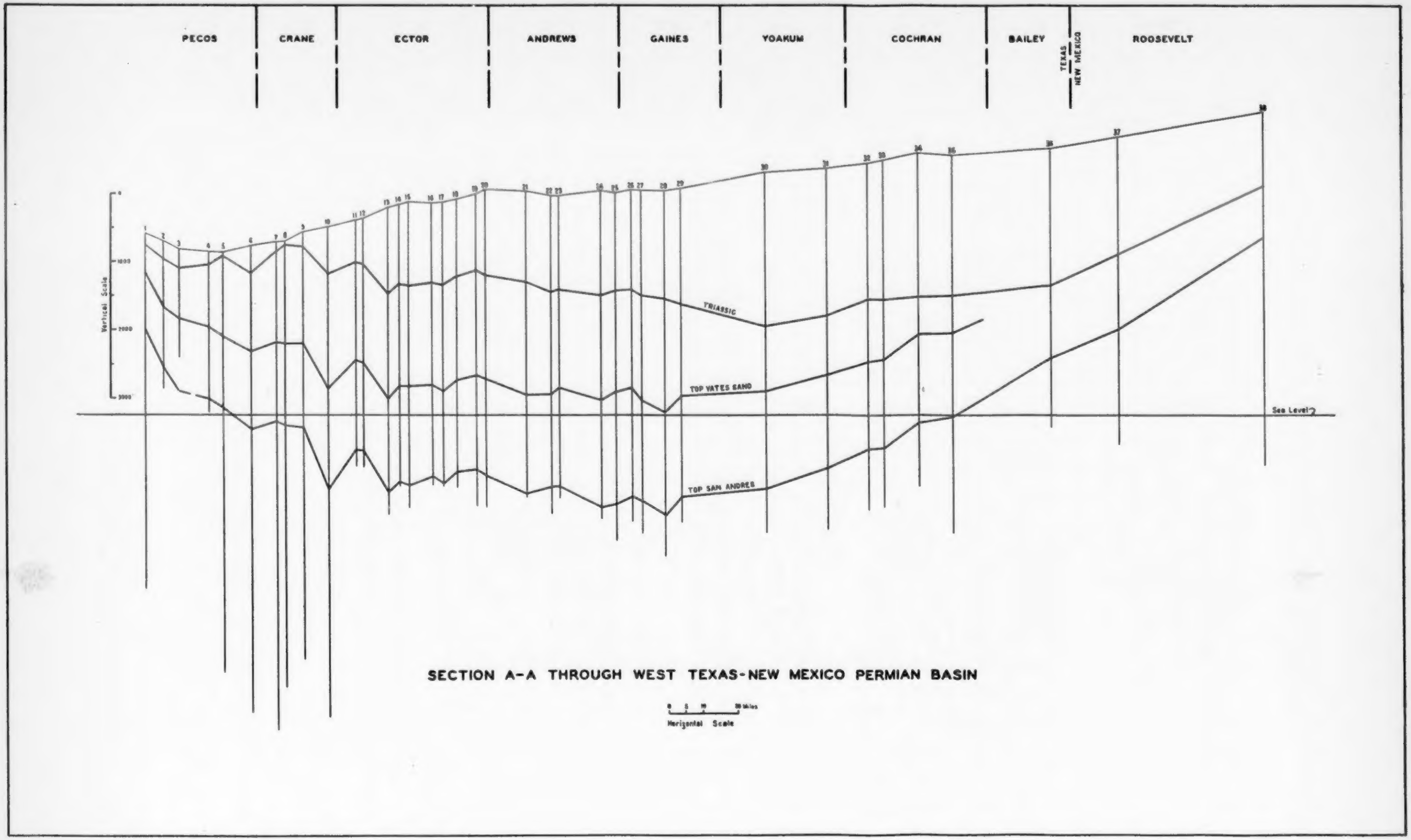

FIG. 1.—Section AA' through West Texas-New Mexico Permian basin.

NOTICE.—A blue-line paper print on a sheet approximately 84×21 inches (scale, 1 inch=4 miles), made up of the detailed lithologic, formational well logs, indicated in skeleton section in Figure 1, showing the stratigraphic correlations, may be obtained if order is sent promptly to A.A.P.G. headquarters, Box 979, Tulsa, Oklahoma. Price per copy, folded in mailing envelope, postpaid: to A.A.P.G. members and associates, colleges, and libraries, \$1.35; to others, \$1.70. On orders for 100 or more, 10 per cent discount.

	Operator	*Well*	*Section*	*Block*	*Survey*	*County*
1.	Shell-Kirby	University No. 1	23	26	Univ.	Pecos
2.	California	Cordova-Union No. 1	10	141	TSTL	
3.	Montague	Masterson No. 1	104	10	H&GN	
4.	Spikes	Brown No. 1	8	3	H&TC	
5.	Magnolia	McKee No. 1-A	24	9	H&GN	
6.	Moore Bros.	Barnsley No. 1	43	32	PSL	Crane
7.	Loffland Bros.	Tubb No. 3	9	27	PSL	
8.	Gulf	Waddell No. 1	4	27	PSL	
9.	Gulf	McKnight No. 3	9	21	PSL	
10.	Wilcox	McKnight No. 1	9	46	G&MMB&A	
11.	Texas	Connell No. 20	26	16	PSL	Ector
12.	Skelly	Connell No. 1	11	16	PSL	
13.	York-Harper	Bates No. 1	38	44	T&P 2S	
14.	Wentz	Moss No. 1	28	44	T&P 2S	
15.	Broderick-Calvert	Parker No. 1	15	44	T&P 2S	
16.	Gulf	Goldsmith No. 4	27	44	T&P 1S	
17.	Gulf	Goldsmith No. 1	10	44	T&P 1S	
18.	Landreth	Scharbauer No. 1	20	44	T&P 1N	
19.	Empire	Cummins No. 1	10	45	T&P 1N	
20.	Grisham-Hunter	Cowden No. 1	10	45	T&P 2N	
21.	Maer-Martin & Kell	Meadors No. 1	8	41	PSL	Andrews
22.	Deep Rock	Kuykendall No. 1	24	46	PSL	
23.	Tripplehorn	Brown No. 1	7	46	PSL	
24.	Wahlenmaier	Cox No. 1	8	33	PSL	
25.	Stogner	George No. 1	25	22	PSL	
26.	Wentz	Dalmont No. 1	5	22	PSL	Gaines
27.	Stanolind	Davis No. 1	18	21	PSL	
28.	Amerada	Fasken No. 1	160	G	WTRR	
29.	Walsh-Adams	Averitt No. 1	228	G	WTRR	
30.	Davidson	Bennett No. 1	678	D	Gibson	Yoakum
31.	Magnolia	Taylor No. 1	201	D	Gibson	
			Labor	*League*	*County School Lands*	
32.	Cascade-Honolulu	Duggan No. 1	13	55	Oldham	Cochran
33.	Wiggens	Dean No. 1	26	92	Lipscomb	
34.	Humble	Slaughter No. 1		135	Armstrong	
35.	Westbrook	Slaughter No. 1	67	188	Knox	
			Section	*Block*		
36.	Humble	Fuqua No. 1	117	A		Bailey
				Township	*Range*	
37.	Sloan-Smith	Lovern No. 1	4	3 South	35 East	Roosevelt, N.M.
38.	Franklin	Gephart No. 1	28	3 North	30 East	

H. P. Bybee and others,[5] Cannon and Cannon,[6] the more recent, although less detailed work of Thompson,[7] and numerous other published and unpublished cross sections have been confined generally to an east-west or northwest-southeast direction. They involve only the southern portion of this broad platform, which is notable for the thick evaporite deposition and reef masses of Permian age, and the underlying more intensely folded pre-Permian sediments.

There is a particular need of the cross section for five reasons.

First, to show the writers' interpretation of the limits of the Upper Castile salt deposition in a south to north direction, and the northern limits of the Upper Castile basin of deposition.

Second, to show from south to north the lateral gradation from dolomite and dolomitic limestones into evaporite and also clastic sediments. This gradation may be particularly noted in the Whitehorse and San Andres groups.

Third, to clarify and establish the relationship for practical correlative purposes of several of the producing members of the Whitehorse and San Andres groups. The limits of all of the members are not defined in this paper.

Fourth, to indicate the suspected correlation of the Glorieta sand (basal sandstone facies) of the San Andres group with the undifferentiated Permian sediments of the southern part of the Central Basin platform.

Fifth, to include the logs of several tests which have penetrated the Lower Ordovician sediments; and to indicate the magnitude of the pre-Permian deformation.

In the preparation of this cross section thirty-eight sample logs are used, compiled from analyses of cuttings from test wells, generally drilled by cable-tool methods; test wells drilled by rotary methods were used only where necessary. Exceptions may be noted particularly in that portion of the logs above the Rustler formation, and are due to the usual failure of both operators and drillers to catch, or preserve, reliable samples above that formation.

Only the carefully prepared percentage logs have been used in the compilation of this cross section; it has been necessary, however, because of the reduced scale and for readily correlative purposes, to

[5] H. P. Bybee, E. F. Boehms, Cary P. Butcher, H. A. Hemphill, and G. E. Green, "Detailed Cross Section from Yates Area, Pecos County, Texas, into Southeastern New Mexico," *ibid.*, Vol. 15, No. 9 (September, 1931), pp. 1087–93.

[6] R. L. Cannon and Joe Cannon, "Structural and Stratigraphic Development of South Permian Basin, West Texas," *ibid.*, Vol. 16, No. 2 (February, 1932), pp. 189–204.

[7] Wallace C. Thompson, "Geologic Sections in Texas and Adjoining States," *ibid.*, Vol. 21, No. 8 (August, 1937), pp. 1083–87.

reinterpret, and introduce them as contact logs as shown. Thus minor breaks in the evaporite or clastic sediments, originally logged as 50–75 per cent of sand, shale, salt, or anhydrite, have been shown as 100 per cent and the thickness of each reduced in ratio to the percentage shown by the original description of the sample.

In this symposium other writers discuss details of stratigraphy peculiar to parts of the formations as shown on this section and may give different interpretations. However, in this cross section the nomenclature and most of the correlations are generally accepted. No attempt is made to establish long-range correlations with previously named strata in areas far removed from the West Texas-New Mexico Permian basin.

Little discussion is given the Silurian, Devonian, Mississippian, and Pennsylvanian systems for the reason that to date no production has been found from sediments of those systems. In most places, if ever present, they have been removed by erosion.

Most emphasis has been given the better known San Andres and Whitehorse groups, and Upper Castile formation, since the geologists in the West Texas-New Mexico Permian basin must frequently deal with these sediments.

PRE-CAMBRIAN

Only two tests, Shell-Kirby, University No. 1 (No. 1) and Loff land Bros., Tubb No. 3 (No. 7) have been drilled into pre-Cambrian rocks.

The older rocks in the Shell-Kirby, University No. 1 have been described by Jones and Conkling,[8] who concluded that they represent a metamorphosed sandstone, cut by veins and stringers of pegmatite or aplite. These rocks are generally considered to be pre-Cambrian. Similar rocks have been encountered in the Loffland Bros., Tubb No. 3, in Crane County in the Sand Hills area.

CAMBRIAN

It is not certain that Cambrian beds are anywhere present but the writers suggest the possibility that the lower part of the dolomite in the Loffland Bros., Tubb No. 3, in Crane County may belong to the Cambrian. That is a problem, however, which can be solved only by detailed research involving careful analysis of the insoluble residues, and a careful search for diagnostic fossils.

[8] E. L. Jones, Jr., and Russell C. Conkling, "Basement Rocks in Shell-Humphreys Well, Pecos County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 3 (March, 1930), pp. 314–16.

ORDOVICIAN

The Ordovician system is represented by two formations, the lowest referred to as the Ellenburger dolomite, and the overlying strata as the Simpson formation. The Ellenburger dolomite represents the Lower Ordovician and possibly the Upper Cambrian, and the Simpson formation is Middle Ordovician.

Ellenburger dolomite.—The Ellenburger dolomite appears on this cross section in the southern portion in Pecos and Crane counties. Usually, tests are drilled about 100–200 feet into the Ellenburger dolomite. They are stopped on encountering either oil in commercial quantities, as shown in the Gulf, McKnight No. 3 (No. 9), or sulphur water as shown in the Magnolia, McKee No. 1-A (No. 5) which was subsequently abandoned, and in the Gulf, Waddell No. 1 (No. 8) which was plugged back to a pay zone in the Simpson formation. An exception is the 1,300 feet of Ellenburger dolomite penetrated by the Loffland Bros., Tubb No. 3 (No. 7), which failed to develop production in the Ellenburger. This test drilled out of basal Permian into Ellenburger, having all the Simpson section truncated and possibly the upper Ellenburger truncated, which may explain the failure to develop Ellenburger production.

The structural relief of the Ellenburger dolomite may be readily noted by considering the different subsea elevations at which it is encountered in the cross section. Between the Magnolia, McKee No. 1-A (No. 5) and the Gulf, McKnight No. 3 (No. 9), or within a distance of 22.8 miles, there is a difference of approximately 1,600 feet. The 500 feet of difference in subsea datums on top of the Ellenburger between the Loffland Bros., Tubb No. 3 (No. 7) and the Gulf, Waddell No. 1 (No. 8) is possibly due to faulting as has been suggested by Cordry.[9]

Simpson formation.—The lithologic characteristics of the Simpson formation are definitely similiar to those usually described in Oklahoma. The pitted, frosted quartz grains, the thick green shales, the occasional red shales, with interbedded limestones and dolomites, differ from the Oklahoma section only in the details of stratigraphic sequence and interval. The lithologic correlation has been substantiated by fossils. Post-Simpson folding, with pre-, or early, Permian truncation, leaves the geologist little clue to the amount of Simpson sediments to be expected, or the first member of the formation to be encountered, until it has been penetrated or encountered by the drill.

[9] C. D. Cordry, "Ordovician Development, Sand Hills Structure, Crane County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 12 (December, 1937), pp. 1575–79.

Due to the truncation, the Simpson formation is most variable in thickness. This may be observed in the range of thickness from 25 feet to 1,270 feet in wells No. 5 to No. 9.

Commercial oil production and showings are known from the sandstones of this formation, and from the evidence to date, it is the opinion of the writers, that the production of oil will be governed by the same general factors as in older producing areas, and, in particular, commercial production from this formation will be limited to closed structures. The Magnolia, McKee No. 1-A (No. 5) encountered excellent showings of oil from several sands of the Simpson formation, and the Gulf, Waddell No. 1 (No. 8) was completed for a producer in this formation.

SILURIAN-DEVONIAN

The Silurian-Devonian systems are represented by an unnamed limestone tentatively called Fusselman.[10] It appears only in the Moore Bros., Barnsley No. 1 (No. 6) in Crane County, and consists of a series of gray to gray-green calcareous shales, siliceous limestones, and thick chert zones, with a definite increase in the chert content in the lower one-third of the formation. Other structurally low wells in the area have encountered similar sediments. There is the possibility that the section referred to may be the Montoya formation, and therefore of Upper Ordovician age.

MISSISSIPPIAN

The Mississippian system is represented on the Central Basin platform, although this system does not appear on the line of this cross section. The Gulf, McElroy No. 103, in the Church-Fields area east of the line of this cross section, found sediments of Mississippian age, while the American-Liberty, Cowden No. 1, in western Andrews County, and west of the line of this cross section, encountered sediments of this age.[11] Those tests encountering sediments of Mississippian age are considered low regionally or off structure. These sediments consist of black fissile shales characteristic of early Mississippian elsewhere in the Mid-Continent.

PENNSYLVANIAN

No sediments of Pennsylvanian age are shown on this cross section. Sediments of this age are found in the Gulf, McElroy No. 103, east of this section, and it is conceivable that a certain amount of these sediments may be found in low wells of the Central Basin platform.

[10] P. D. Moore, personal communication.

[11] D. M. Secor, P. D. Moore, and others, personal communications.

PERMIAN

The strata referred to the Permian system occupy a larger interval than the total of all other ages shown on the cross sections. The structurally low Wilcox, McKnight No. 1 (No. 10) has approximately 6,480 feet of Permian sediments, and the base of the system was not reached in this well.

The system is divided into seven parts, which, in ascending order, are as follows: Abo, Yeso, San Andres, Whitehorse, Upper Castile, Rustler, post-Rustler.

Abo formation.—The Abo formation is shown in but one well, Franklin, Gephart No. 1 (No. 38), in which approximately 200 feet were penetrated. This section of fine gray sands and dark red sands and shales shows at its top an ideal stratigraphic break between the predominantly clastic sediments of the Abo and the predominating evaporites of the overlying Yeso formation, a break also characteristic of the outcrops. The lighter redbeds of the Yeso further emphasize the color change at this contact, which is used as a subsurface key bed in parts of New Mexico.

Probably Abo equivalents never completely covered the Central Basin platform. If the platform was ever covered by Abo deposits, they were removed by pre-Yeso erosion.[12]

Yeso formation.—The Yeso formation and its time equivalents contain the oldest sediments of the Permian system to be shown on both extremities of the cross section. The correlation of the Yeso is extended southward from unquestioned subsurface occurrences in New Mexico, but no attempt is made to show the relation of its southern equivalents to the outcrops of the Glass Mountains and the Guadalupe Mountains and the east side of the Permian basin.

These beds were deposited unconformably on the Abo formation as shown at the northern terminus of the cross section and on pre-Permian sediments of different ages as shown in wells No. 1 to No. 9 inclusive in the southern part of the cross section.

In the Franklin-Gephart test (No. 38) 1,850 feet of sediments are classed as Yeso. This succession of clastics and evaporites includes a preponderance of sandstone in the lower and upper parts of the formation, while the middle is essentially evaporites.

Few other tests near the northern end of the cross section have entered and none have entirely penetrated the Yeso. Wells No. 35 and No. 37 show approximately 100 and 300 feet, respectively, and, as compared with No. 38, the lithology of the sediments is materially

[12] Some geologists believe that several hundred feet of the lower Permian limestone in the Shell-Kirby, University No. 1, is of Wolfcamp (Abo) age.—Editorial note.

different. They include notably red shales and gray and tan dolomites.

The records indicate that the Gephart test was drilled near the southern limit of a salt basin of Yeso age.

The first ten logs at the southern end of the cross section show the suggested time equivalent of the Yeso. These massive dolomite and limestone strata, with the occasional chert, sand, black shale, and anhydrite interdigitations, have been correlated with the Yeso on the basis of statigraphic sequence and interval. Similar lithologic changes are known at the outcrop in southern New Mexico.

The base of the formation in this cross section unconformably overlies pre-Permian strata. The top of the formation is not definitely known, but it is probably near the oil-producing zone referred to as the Tubb "pay" in the Sand Hills pool, and approximately 100 feet below the line drawn on the cross section representing the top of the Glorieta member on wells No. 5 to No. 10.

In the Sand Hills area oil is produced from the pay strata at or near the top of this formation from depths between 4,280 and 4,420 feet. Initial potentials as high as 8,200 barrels of oil per day have been assigned to wells producing from this zone. These producing strata are the oldest of Permian age known on the Central Basin platform. Other pools produce from younger Permian at greater depth. A few tests have been drilled to this zone that were not well located structurally, or else found no porosity, and have been abandoned. It is anticipated that many other pools that will produce from this formation remain to be developed.

SAN ANDRES GROUP

The San Andres group extends the full length of the cross section, its thickness ranging from approximately 1,300 feet to 1,700 feet (if the sandstone in the Sand Hills area is Glorieta). The predominantly fine to coarsely crystalline dolomite with here and there interstratified characteristic black shales and cherts shown in the southern part of the cross section grades northward into an evaporite sequence of which the upper part is principally salt and anhydrite, while the lower part retains some of the characteristic crystalline dolomite with black shale and chert breaks.

The primarily clastic basal formation of this group is known as the Glorieta sandstone. It unconformably overlies the Yeso formation, and is generally easily recognized in logs because of its characteristic sandstones, which are fine and gray at the top of the member and coarser toward the base. The thickness ranges from 100 to 150 feet. The sands are most prominent in the northern wells of the cross sec-

tion. Near the southern end remnants are the only suggestion of the thick sands elsewhere.

Lateral gradation in evaporite deposition is shown in the upper part of the San Andres. In the first twenty-seven logs, extending from central Pecos to central Gaines County, or approximately half the length of the cross section, the upper part is predominantly dolomite. This dolomite shows an increasing percentage of anhydrite in a northerly direction as shown in wells No. 27 to No. 35. Between wells No. 35 and No. 36 is further gradation; in that 28.3 miles salt appears. Salt increases and further gradation of dolomite to anhydrite is indicated by wells No. 35 to No. 38. In No. 38 approximately 50 per cent of the entire San Andres group is salt.

Porosity, with attendant commercial production of oil under favorable environment, is shown in almost every part of the dolomite or limestone facies of the group, and the horizon of production descends as the upper part grades progressively northward into evaporites.

Of interest is the fact that ordinarily the porosity is developed somewhat below a minor interruption of the dolomite deposition, or just below a clastic break.

Most of the oil produced in Ector, Andrews, Gaines, Yoakum, Cochran, and Hockley counties, Texas, as well as from the Hobbs and Vacuum and recently discovered Lovington pools in Lea County, New Mexico, is from sediments of San Andres age.

WHITEHORSE GROUP

The Whitehorse group unconformably overlies the San Andres group, with a thickness varying from approximately 1,300 feet to 1,650 feet.

In the West Texas-New Mexico Permian basin the Whitehorse group is divided from the base upward into five formations: Grayburg, Queen, Seven Rivers, Yates, Tansill. These are discussed separately by Robert I. Dickey in a companion paper, therefore their detailed descriptions are not repeated here. The Grayburg, Queen, and Seven Rivers are not distinguished on the cross section, but the Yates sand, that indispensable key bed, is shown. The top of the Whitehorse is properly the top of the Tansill, but this horizon is difficult to determine in many wells; consequently, a slightly higher horizon, the base of the salt, is used as the top of the Whitehorse on the cross section.

Yoakum dolomite member.—On the cross section (wells No. 30 to No. 35) in the lower part of the Whitehorse group is a line marking

the horizon of the top of a thin but persistent dolomite member. The attempt is made to trace this horizon southward all the way to the south end of the cross section.

This dolomite member is a useful key bed in Yoakum and surrounding counties. It is commonly referred to as the "brown lime," or, as there are numerous different "brown limes" in West Texas and New Mexico, sometimes referred to as the "Yoakum brown lime," it is proposed to name this bed the Yoakum dolomite member and to designate well No. 30 as the type-locality well.

Well No. 30, formerly Davidson, now Honolulu-Cascade, Bennett No. 1, is the discovery well of the Bennett field and of Yoakum County. It was drilled with cable tools in the center of the NE. ¼ of Sec. 678, Blk. D, John H. Gibson survey. The elevation of the derrick floor was 3,557 feet above sea-level, and the total depth, 5,282 feet. It was completed in April, 1936.

The following is a sample description of the type section.

Depth in Feet	
4,150–4,160	40 per cent anhydrite; 50 per cent red sand; 10 per cent red shale; trace of frosted quartz grains
–4,170	25 per cent anhydrite; 55 per cent red sand; 20 per cent red shale; abundant frosted quartz grains
–4,180	20 per cent anhydrite; 60 per cent red sand; 20 per cent red shale; frosted quartz grains; small quartz crystals
	TOP YOAKUM DOLOMITE MEMBER, 4,180
–4,195	20 per cent dense brown dolomite; 10 per cent porous brown dolomite; 40 per cent brown sandy dolomite; 30 per cent gray dolomitic sandstone; trace of red shale with small quartz crystals
–4,215	20 per cent brown dolomite; 20 per cent brown sandy dolomite; 40 per cent gray dolomitic sandstone; trace of gray shale; trace of anhydrite; 20 per cent fine red sand
	BASE YOAKUM DOLOMITE MEMBER, 4,215
–4,230	10 per cent brown sandy dolomite; 15 per cent anhydrite; 45 per cent red shaly sand; 30 per cent red shale; small quartz crystal; trace of pyrite; trace of frosted quartz grains
–4,240	trace of brown dolomite; 10 per cent anhydrite; 80 per cent red sand; 10 per cent red shale; frosted quartz grains

Samples of this type section are on file in the office of the Honolulu Oil Corporation, Midland, Texas, and in the files of several other large companies in the area.

The Yoakum dolomite is a member of the Queen formation of the Whitehorse group.

Yates sand.—The Yates sand is the most persistent lithologically of all formations of Whitehorse age in the West Texas-New Mexico Permian basin, and the top of the Yates is indicated on all logs in the cross section. It serves as a key horizon for the subsurface of the region because of its wide areal extent. The Yates immediately adja-

cent to the Capitan reef is composed of 200–300 feet of calcareous sandstone. Farther back in the lagoon the amount of sand deposited was materially less, and anhydrite and salt are representative of that deposition; however, there is ordinarily a dolomite stringer at the base of a sand in the lower part of the Yates and the thickness is approximately the same. For practical correlative purposes the Yates is recognized as the sand zone which carries the first frosted quartz grains below the base of the salt. This is the diagnostic characteristic in an area extending far beyond the limits of the Central Basin platform, including the Midland basin and the area eastward to its outcrop. Subsurface geologists familiar with the area will differ in choosing the top of the Yates by only a few feet, and those differences are generally due to poor samples.

Oil from Whitehorse.—The sediments of Whitehorse age have been particularly interesting to the petroleum geologist as a source of excellent production. Most of the oil from the Central Basin platform is from sediments of the Whitehorse sea. Notable oil fields on the platform producing from these strata are Yates, McCamey, Church and Fields-McElroy, Estes, Shipley, Grand Falls, O'Brien, Halley, Hendrick, Sayre, Scarborough, Jal, Cooper, Eunice, and the pools in the "sand belt" of eastern Lea County.

Porosity, with commercial production under proper environment, is found in some part of each formation of the Whitehorse group. The oil of the Shipley pool in Ward County and the Stuart areas east of Jal, New Mexico, is from sands that should probably be referred to the Queen formation. The Yates, Estes, O'Brien, Hendrick, Halley, Jal, Cooper, and Lea fields produce from the upper Seven Rivers and Yates.

The Yates sand covers a much larger area, and more pools produce from it than from the others. In fact, even in areas where the youngest strata producing oil are San Andres, the Yates sand in many places has excellent showings of gas, and is noted for its exceptionally high rock pressures. These showings commonly serve to indicate the approximate position of the top of the Yates where that key horizon is obscured by poor samples.

Upper Castile formation.—The Upper Castile formation is mostly salt and therefore generally easily recognizable. In this cross section the northern and southern limits of salt deposition are shown. The variable thickness of the salt is obvious.

The Upper Castile unconformably overlies the Whitehorse. Possible evidence of this unconformity is furnished by the sand and red shale at the base of the main salt. This is observed by the driller in

most tests on the Central Basin platform, as it caves readily. Cavings from these strata sometimes cause the drill pipe to stick in the underlying dolomites of the Whitehorse.

Geologists are not agreed that this zone marks the base of the Upper Castile formation, and would place the contact at the top of the Carlsbad limestone (that is, the top of the Tansill formation). Because the Carlsbad limestone grades into anhydrite, the writers prefer the base of the salt as the most desirable contact. The maximum difference is 50 feet and therefore of little consequence in regional work. Incidentally the redbed and sand member referred to is not easily recognized in rotary samples and not shown in all sample descriptions, because it is generally considered contamination by the microscopist.

From 100 to 150 feet above the base of the salt is a conspicuous, persistent member long known to local geologists as the Cowden anhydrite. It will be formally defined in a forthcoming paper on the North Cowden field by Giesey and Fulk. This member appears rather consistently over the entire Central Basin platform. It is characteristically a dark to light gray, locally dolomitic anhydrite between 20 and 40 feet thick. Its probable southward gradation into dolomite is indicated on the cross section by wells No. 3 and No. 4. It commonly serves as a control from which the base of the main salt or the top of the Yates may be estimated.

The salt of the Upper Castile above the Cowden anhydrite is variable in thickness. The double anhydrite member near the top of the salt is commonly an aid in estimating the position of the base of the salt in advance of the drill. Extreme thinning between the double anhydrite member and the top of the Rustler formation is common, especially over local domes and anticlines on the platform. This is considered evidence of the loss of salt by solution. In this connection attention is called to the loss of salt in wells No. 7 to No. 11.

No commercial production of oil or gas is known from beds of Upper Castile age; however, non-inflammable gas has been obtained from the Cowden anhydrite member over structurally high areas in central Gaines County, Texas.

Rustler formation.—The Rustler unconformably overlies the Upper Castile. The top of the Rustler is usually referred to by subsurface geologists and in scout reports as the "Top anhydrite."

The thickness of the Rustler is variable. From 50 to 300 feet is shown on the cross section. In other places it attains a thickness of more than 400 feet. It has been removed by erosion, if ever present,

near the northern end of the cross section as shown between wells No. 35 and No. 36. Local thinning is generally due to high position on structure that caused a loss of salt through solution.

The Rustler formation consists of a sequence of sand, anhydrite, and in places dolomite members. In some areas salt is present both above and below the dolomite members. Throughout much of the Central Basin platform the dolomite members are porous. In some wells good showings of oil have been encountered and large quantities of water are not uncommon. Commercially the Rustler is of negligible value.

Post-Rustler.—The post-Rustler section of Permian age, locally consisting of several hundred feet of red sandstone and shale, is not discussed in this paper, since it will be discussed in detail by other authors, elsewhere in this symposium. Post-Permian beds are omitted for the same reason.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 1 (JANUARY, 1940), PP 29-36, 1 FIG.

SOUTH-NORTH CROSS SECTION FROM PECOS COUNTY THROUGH WINKLER COUNTY, TEXAS, TO ROOSEVELT COUNTY, NEW MEXICO[1]

E. HAZEN WOODS[2]
Midland, Texas

ABSTRACT

The cross section extends from the Shell-Kirby's University well No. 1 in Pecos County, Texas, northward to Sloan and Smith's Lovern well No. 1 in Roosevelt County, New Mexico. The Permian producing beds, the San Andres and Whitehorse groups, and their gradation from dolomite in the south to anhydrite and salt in the north are shown. The northern and southern limits of the basin of deposition of Upper Castile salt are indicated.

ACKNOWLEDGMENT

The writer is indebted to the Sinclair Prairie Oil Company whose records, help, and permission to publish have made this paper possible. Acknowledgments are made to James FitzGerald, Jr., Dana Secor, and W. C. Fritz for sample logs and suggestions; to Ronald K. DeFord, E. Russell Lloyd, and John M. Hills for valuable criticisms and suggestions; and to Charles G. Langford for drafting.

INTRODUCTION

Most previous sections have crossed the West Texas Permian basin from east to west.[3] The cross section of Bybee and others[4] was double. Both lines started at the Yates field, Pecos County, Texas, and extended generally northwestward; but one line followed the west side of the Central Basin platform and ended at Carlsbad in central Eddy County, New Mexico,[5] while the other followed the east side of the platform and ended near the northwest corner of Eddy County. Three short sections connected these main lines.

The present cross section begins at the Shell-Kirby's University well No. 1 (No. 1 on section) on the Fort Stockton "high," Pecos County, Texas, about 40 miles west of the Yates field. It extends northward along the west side of the Central Basin platform into

[1] Read before the Association at El Paso, September 29, 1938. Manuscript received, August 11, 1939.

[2] Sinclair Prairie Oil Company.

[3] Lon D. Cartwright, Jr., "Transverse Section of Permian Basin, West Texas and Southeast New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 8 (August, 1930), pp. 969-81.
R. L. Cannon and Joe Cannon, "Structural and Stratigraphic Development of South Permian Basin, West Texas," *ibid.*, Vol. 16, No. 2 (February, 1932), pp. 189-204.
Wallace C. Thompson, "Geologic Sections in Texas and Adjoining States," *ibid.*, Vol. 21, No. 8 (August, 1937), pp. 1083-87.

[4] H. P. Bybee, E. F. Boehms, Cary P. Butcher, H. A. Hemphill, and G. E. Green, "Detailed Cross Section from Yates Area, Pecos County, Texas, into Southeastern New Mexico," *ibid.*, Vol. 15, No. 9 (September, 1931), pp. 1087-93.

[5] On the west sections of Bybee *et al.* the top of the Yates sand is miscalled "the top of the Queen sand zone."—Editorial note.

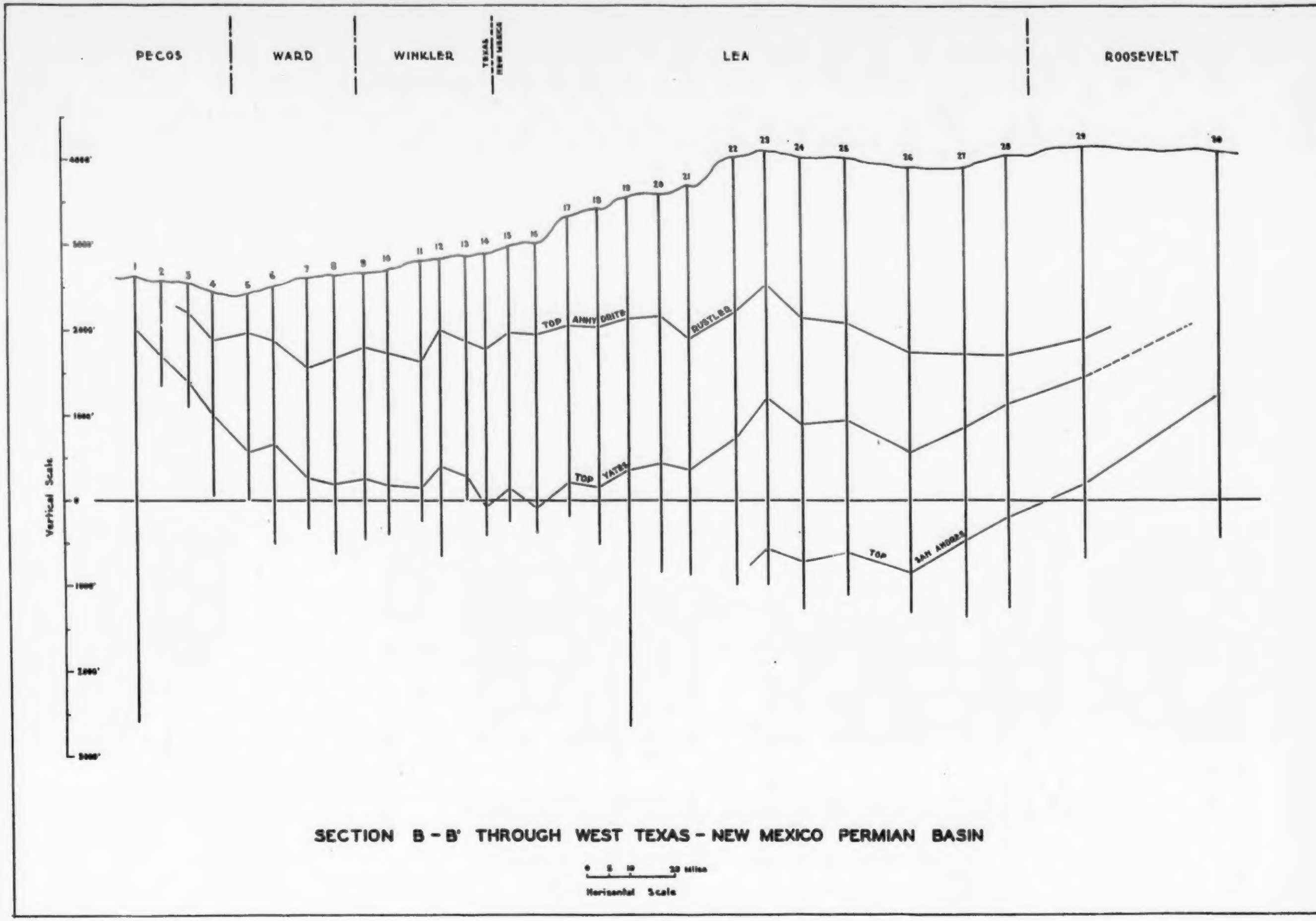

FIG. 1.—Section *BB'* through West Texas-New Mexico Permian basin.

NOTICE.—A blue-line paper print on a sheet approximately 72×20 inches (scale, 1 inch=4 miles), made up of the detailed lithologic, formational well logs, indicated in skeleton section in Figure 1, showing the stratigraphic correlations, may be obtained if order is sent promptly to A.A.P.G. headquarters, Box 979, Tulsa, Oklahoma. Price per copy, folded in mailing envelope, postpaid: to A.A.P.G. members and associates, colleges, and libraries, $1.10; to others, $1.35. On orders for 100 or more, 10 per cent discount.

	Operator	Well	Section	Block	Survey
1.	Shell-Kirby	University No. 1	23	26	University Lands
2.	Polk	Rooney No. 1	18	140	T. & St. L. R.R.
3.	Quinby	Bennett No. 2	592	105	G. C. & S. F. R.R.
4.	Shell	Jackson No. 1	28	3	H. & T. C. R. R.
5.	T. P. C. & O. Co. & Atlantic	Buckner No. 1	3	32	H. & T. C. R. R.
6.	Sinclair Prairie	Archenhold No. 12	23	5	H. & T. C. R. R.
7.	Gulf	Estes No. 1	38	34	H. & T. C. R. R.
8.	Gulf	Hutchings No. 2	7	0	G. & M. M. B. & A.
9.	Sinclair Prairie	Sealy Estate No. 2	95	A	G. & M. M. B. & A.
10.	Skelly	Halley No. 1	25	B-11	P. S. L.
11.	Gulf	Hendricks No. 1	34	B-5	P. S. L.
12.	Maxwell	Clapp No. 1	37	26	P. S. L.
13.	Sayre	Howe No. 1	12	26	P. S. L.
14.	Texas	Daugherty No. 1	2	74	P. S. L.

	Operator	Well	Section	Township South	Range East
15.	Texas	Rhodes No. 1	22	26	37
16.	Skelly	Joyner No. 1	26	25	36
17.	Cranfill and Reynolds	Meyers No. 1	22	24	36
18.	Cranfill and Reynolds	State "C" No. 1	16	23	36
19.	Ohio	State-McDonald No. 5	16	22	36
20.	Continental	Reed No. 1	22	20	36
21.	Exploration	Record No. 1	25	19	35
22.	Culbertson *et al.*	State No. 1	22	18	34
23.	Texas	Bridges No. 1	17	17	34
24.	Magnolia	Eidson-Scharbauer No. 1	29	16	35
25.	Galt-Brown	State No. 1	9	15	35
26.	Reynolds	Anderson No. 1	29	13	37
27.	Morton	State No. 1	32	11	38
28.	C. O. & M.	Maxwell No. 1	2	11	36
29.	M. C. & O.	Williamson No. 1	7	8	36
30.	Sloan & Smith	Lovern No. 1	4	3	35

New Mexico, and on northward through Lea County to Sloan and Smith's Lovern well No. 1 (No. 30 on section) in Roosevelt County, New Mexico, a total distance of approximately 260 miles by line of section. (See Fig. 3, Editorial Introduction.) The two end wells are also in the companion cross section of FitzGerald and Fritz in this symposium. The Exploration's Record No. 1, and Culbertson *et al.*, State No. 1 (Nos. 21 and 22 on section) in Lea County, New Mexico, are common to the present cross section and the companion east-west section of Dickey in this symposium.

The present cross section is summarized in the skeleton outline (Fig. 1).

The logs are interpretative contact logs made from percentage sample logs with percentages often greatly exaggerated at tops of formations or contacts. Logs from deep cable-tool wells are used as far as possible. Elsewhere rotary wells are used. In some rotary wells part of the salt section has been taken by correlation from adjoining cable-tool wells. Hence this cross section should be considered as giving a generalized picture and not an absolutely accurate one.

It is the purpose of this paper to give a general view rather than a detailed description of the changes encountered in the Permian producing beds along the west side of the Central Basin platform from near its southern end to the Monument field, thence across the San Simon syncline to the Vacuum field, and thence northeastward to tie in with Fritz and FitzGerald's section.

On the west side of the Central Basin platform the cross section does not follow the line of oil fields along the very edge but passes a few miles east of them; for on the east the wells penetrate deeper and reveal more of the stratigraphy.

Except for a few wells at the north end of the section the average spacing between wells is 7 miles. As cable-tool wells are rare in the newer fields in New Mexico, near-by cable-tool wells are used in the cross section in preference to the rotary wells within such fields as Monument and Vacuum.

Location, depth, elevation, showings of gas, oil, and water, and production data are from scout reports.

STRATIGRAPHY

PRE-PERMIAN ROCKS

Pre-Cambrian[6] material is found only in the Shell-Kirby's Univer-

[6] E. L. Jones, Jr., and Russell C. Conkling, "Basement Rocks in Shell-Humphreys Well, Pecos County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 3 (March, 1930), pp. 314–16.
E. H. Sellards, "The Pre-Paleozoic and Paleozoic Systems of Texas," *Univ. of Texas Bull. 3232* (August, 1932), pp. 52–53.

sity well No. 1 (No. 1 on section) in Pecos County. The concentration of a few minerals in several samples suggests metamorphic rock or reworked granite.

Paleozoic systems older than Permian are not represented on this cross section. Rocks of Ordovician age probably underlie part of the area north of the Shell-Kirby's University well No. 1, but no well[7] has been drilled to test the Ordovician near the line of the section.

OLDEST PERMIAN ROCKS

The cross section deals mainly with the upper San Andres and younger beds. An approximately complete section of older Permian is represented in the Shell-Kirby's University well No. 1, but no attempt is made to subdivide it. The position of the Yeso is shown in only one well, the Sloan and Smith's Lovern well No. 1 in Roosevelt County, New Mexico, at the extreme north end of the cross section. In this well the Yeso consists of interbedded red silty shale with some gray silty shale, sand, salt, anhydrite, and dolomite.

SAN ANDRES GROUP

The Glorieta, basal sandstone of the San Andres, is shown in the Sloan and Smith's Lovern well No. 1, and its approximate position is shown in the Ohio's State-McDonald well No. 5 (No. 19 on section). The Glorieta consists of about 100 feet of red and gray silty shale and sand, and salt.[8]

The San Andres group overlies the Yeso formation and underlies the Whitehorse group. The San Andres is ordinarily brown dolomite with varying amounts of chert and black shale. It has a thickness of 1,270 feet, exclusive of the Glorieta, in the Sloan and Smith's Lovern well No. 1. The San Andres grades northward from predominant dolomite in The Texas' Bridges well No. 1 (No. 23 on section) to interbedded anhydrite, salt, and dolomite in the Sloan and Smith's Lovern well No. 1. Toward the south the top of the formation is difficult to determine accurately. In the northernmost part of the cross section the top of the San Andres is placed at the top of the predominantly dolomite and anhydrite section and at the base of the red shale and sand section, which is basal Whitehorse. Dolomite builds up toward the south and is found above the top of the San Andres

[7] Since this was written the Anderson-Pritchard's Masterson well No. 1 encountered Ordovician at 4,540 feet about 10 miles east of the line of section. Three miles east of the Shell's Jackson well No. 1 (No. 4 on section) the Magnolia's Abell-Eaton well No. 2 encountered the Ordovician at 5,120 feet.—Editorial note.

[8] Some geologists believe that the Glorieta is represented in the subsurface by the sandstone at the base of the San Andres and that the underlying salt and associated red sands and shale belong in the Yeso. In fresh cuttings their Glorieta is commonly gray sand that takes on the yellow color of the Glorieta outcrops after a few days exposure to the air.—Editorial note.

south of the Galt-Brown's State well No. 1 in Sec. 9, T. 15 S., R. 35 E. (No. 25 on section).

Production from the Vacuum field and the newly discovered Lovington field is from porous dolomite in the San Andres.

WHITEHORSE GROUP

The Whitehorse group occupies the interval between the base of the Upper Castile and the top of the San Andres. In the southern part of the area traversed by the cross section the Whitehorse group consists of interbedded dolomite, sand, and a little anhydrite. Farther north the dolomite grades into anhydrite and salt. There the thickness varies from 1,230 to 1,540 feet.

Along the west side of the Central Basin platform, the Whitehorse is predominantly dolomite with interbedded sand and some anhydrite which increases in amount together with the appearance of salt on the east as is evident by comparison with the parallel section by Fritz and FitzGerald. Between the Ohio's State-McDonald well No. 5 (No. 19 on section) and the Continental's Reed well No. 1 (No. 20 on section) numerous beds of anhydrite appear in the section and increase in importance toward the north. In the Sloan and Smith's Lovern well No. 1 the Whitehorse consists almost entirely of salt and sand.

Other authors in this symposium have divided the Whitehorse group into five formations named from top to bottom as follows: Tansill formation, Yates sandstone, Seven Rivers formation, Queen sandstone, and Grayburg formation. No attempt is made on the accompanying section to show all these subdivisions.

The Grayburg, the lowest formation of the Whitehorse, is shown in four wells, Nos. 22, 23, 24, and 25 of the section. The formation is named and described by Robert I. Dickey in this symposium. The writer is indebted to Dickey for the correlation of the Grayburg formation on this section. In The Texas' Bridges well No. 1 (No. 23 on section) the formation consists of dolomite with interbedded sandstone and minor beds of anhydrite. Farther north the dolomite grades into anhydrite.

The limits of the Queen sandstone and the Seven Rivers formation are not shown on the section. Much of the salt in the Whitehorse in the Magnolia's Eidson-Scharbauer No. 1 (No. 24 on section) and in wells on the north is in the Seven Rivers formation.

The top of the Yates sand, which is shown on the section, is one of the best known and most reliable widespread stratigraphic key horizons in the Permian basin. It is characterized by the first frosted quartz grains found below the base of the main, Upper Castile salt.

Above the Yates sand is the Tansill formation,[9] consisting of dolomite and anhydrite. Because of convenience in correlation the top of the Whitehorse is drawn at the base of the main salt, thus including in the Whitehorse 25–50 feet of anhydrite which more properly belongs in the base of the overlying Upper Castile.

The Tansill formation and the upper part of the Yates sand are absent due to erosion and overlap of younger beds at the north end of the cross section in Sloan and Smith's Lovern well No. 1. This part of the section is now occupied by beds of Triassic age.

All the present production of oil and gas along the line of this section from Pecos County north to, but not including, the Vacuum pool is from Whitehorse beds below the top of the Yates. Production from the Whitehorse is from both porous dolomite and sand.

Upper Castile formation.—The Upper Castile salt and anhydrite section is best developed between the south line of Ward County, Texas, and northern Lea County, New Mexico. It gradually pinches out, due both to non-deposition and erosion, from a maximum thickness of 1,400 feet in The Texas' Daugherty well No. 1 (No. 14 on section) until it entirely disappears between the M. C. and O's. Williamson No. 1 (No. 29 on section) and the Sloan and Smith's Lovern No. 1.

The anhydrite members become less pronounced toward the north. The best marker is the Cowden[10] anhydrite about 200 feet above the base. The top of the formation is irregular, owing in large part to the removal of the upper salt beds by solution.

Potash is the only economic product of the Upper Castile.

Rustler formation.—The Rustler, which overlies the Upper Castile unconformably, consists of a maximum thickness of 450 feet of porous dolomite and limestone, anhydrite, red and gray sandy shale, and salt. The porous dolomite generally contains large quantities of salt water. In test wells the top of the first anhydrite is commonly considered the top of the Rustler, except where it has been removed or has graded into dolomite. The Rustler is absent in the end wells of the cross section.

Post-Rustler formations.—The post-Rustler formations are mainly red shales and sands. Few samples of these beds are caught and saved and fewer are studied. Where available they have been shown on the cross section.

The first redbeds above the Rustler contain very little or no mica. Large rounded frosted quartz grains are common immediately above

[9] Defined by DeFord, Riggs, and Wills in a forthcoming paper.

[10] Defined by Giesey and Fulk in a forthcoming paper on the "North Cowden Field, Ector County, Texas."

the "Top anhydrite," that is, the top of the Rustler. These redbeds are named Dewey Lake by Page and Adams in this symposium and are placed in the Permian.

The Dewey Lake is not distinguished in the cross section from the overlying Tecovas formation, which is placed by Adams in the Triassic.

Above the Tecovas is the Santa Rosa sandstone ordinarily consisting of medium to coarse micaceous red sand.

The overlying redbeds are also placed in the Triassic. Gray sandstones occur here and there, but red is the predominant color. Mica is a common constituent of Triassic beds.

Comanche limestone is found in only one well on this cross section: the Shell-Kirby's University well No. 1.

Post-Cretaceous silt, sand, and caliche of variable thickness covers the surface of the High Plains and is therefore the uppermost formation in all other wells than the Shell-Kirby's University No. 1. It rests on Triassic or Permian redbeds.

Salt Deposition

Many data from the study of Permian stratigraphy in this region illustrate the southwestward retreat of the Permian sea. The relation between anhydrite and limestone shown on the cross section is one example. Another striking example is the manifest southward shift of the conditions of extreme salinity that accompany the deposition of salt (halite). Salt deposition was, of course, interrupted, not continuous; generally, salt ceased to deposit in one local "basin" for a certain time before it began to deposit again in the next younger local "basin" farther south. Nevertheless, the southward shift is a striking feature of the cross section.

Salt deposition started at the north in the area of the Sloan and Smith's Lovern well No. 1 in earlier Permian, Yeso, time; continued through the San Andres and into the Whitehorse; spread southward in early Whitehorse time to the Magnolia's Eidson-Scharbauer well No. 1 (No. 24 on section); then southward near the end of Yates deposition to the Culbertson *et al.* State well No. 1 (No. 22 on section); then southward to the Exploration's Record well No. 1 (No. 21 on section) during Tansill time. The most widespread salt deposition, which took place in Upper Castile time, extended as far south as the Shell's Jackson well No. 1 (No. 4 on section) in Pecos County, Texas. In Rustler time salt deposition was limited to the north-central part of the area.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 1 (JANUARY, 1940), PP. 37-51, 1 FIG.

GEOLOGIC SECTION FROM FISHER COUNTY THROUGH ANDREWS COUNTY, TEXAS, TO EDDY COUNTY, NEW MEXICO[1]

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ABSTRACT

The geologic section presented herewith has been compiled from sample logs of the West Texas-New Mexico Permian basin. It shows chiefly the continuity of the formations of the Whitehorse group from the east side to the west side of the basin. The gradation of sediments in the San Andres and Clear Fork from a shale and evaporite section on the east side outcrop to an almost solid dolomite section in the subsurface in the basin is brought out by the large scale of the section and detailed character of the logs. The Grayburg formation, the oldest formation of the Whitehorse group in the West Texas Permian basin, is defined in this paper.

INTRODUCTION

Geologic workers in the West Texas Permian basin have known for some time that the subsurface of the deepest part of the West Texas Permian basin represents a more complete Triassic and Permian section down to the top of the "Blaine of Texas" or San Andres, as it is now known, than will ever be known from surface work. It is felt, furthermore, that West Texas geology has matured sufficiently to subdivide the larger groups of sediments into smaller units and hence achieve finer and more accurate correlations. The geologic section presented here is an attempt to show these correlations from the outcrop on the east side to the outcrops on the west side of the Permian basin.

Previous geologic sections which have crossed the eastern area of outcrop have had their western termini at the surface section exposed at Guadalupe Point in Culberson County, Texas.[3] Such sections can not, of course, show the continuity of the formations of the Whitehorse group or correlate the top of the San Andres from one side of the basin to the other because the western end is in a different facies from that on the eastern end.

In order to show the continuity of the five formations of the Whitehorse group and the correlation of the top of the San Andres from the east to the west side of the Permian basin, a line of wells was

[1] Read before the Association at El Paso, September 29, 1938. Published by permission of the Stanolind Oil and Gas Company. Manuscript received, August 14, 1939.

[2] Stanolind Oil and Gas Company. Present address: Forest Development Corporation.

[3] Lon D. Cartwright, Jr., "Transverse Section of Permian Basin, West Texas and Southeast New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 8 (August, 1930), pp. 969–81.
Wallace C. Thompson, "Geologic Sections in Texas and Adjoining States," *ibid.*, Vol. 21, No. 8 (August, 1937), pp. 1084–85.

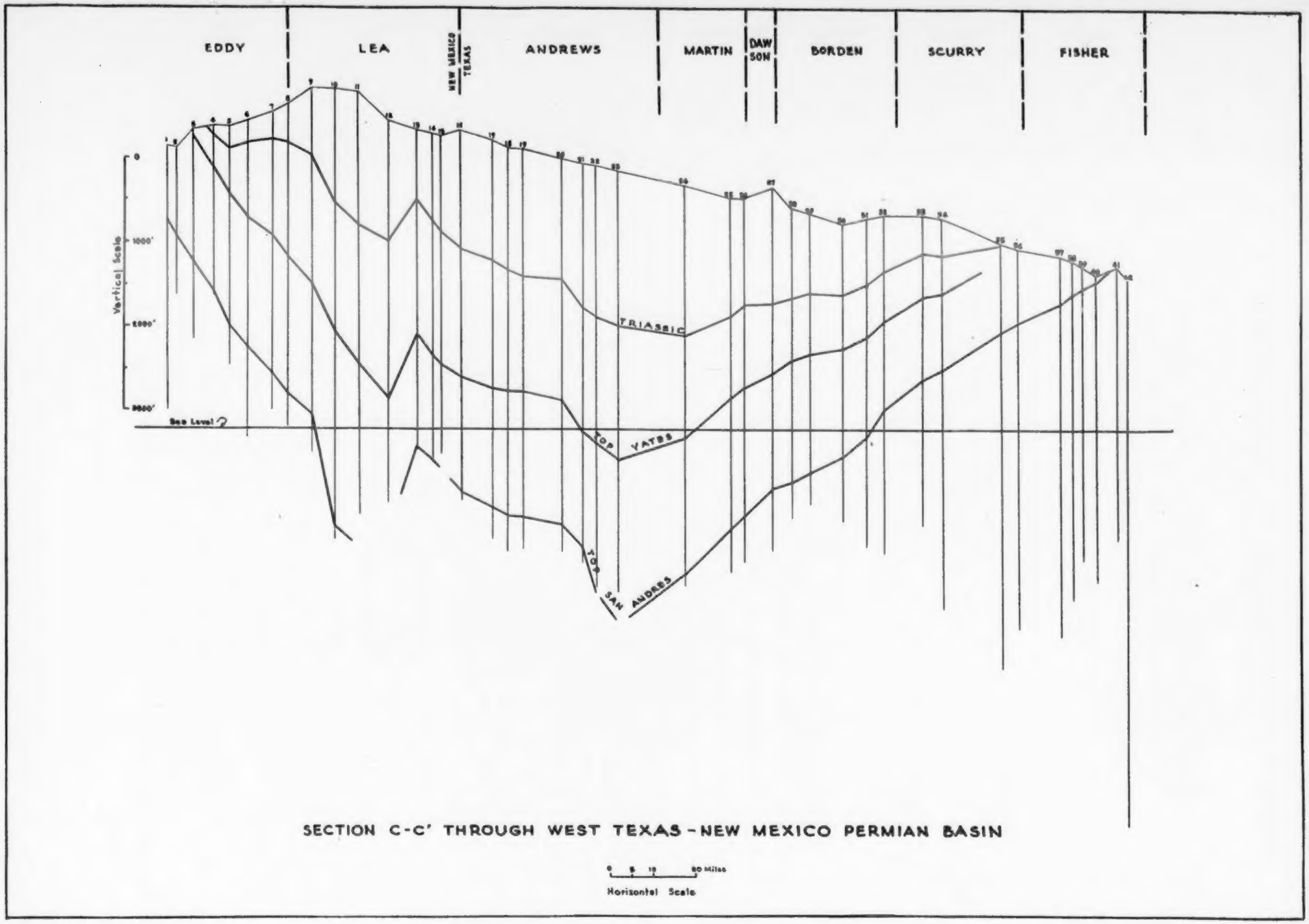

FIG. 1.—Section *CC'* through West Texas-New Mexico Permian basin.

NOTICE.—A blue-line paper print on a sheet approximately 75×27 inches (scale, 1 inch=4 miles), made up of the detailed lithologic, formational well logs, indicated in skeleton section in Figure 1, showing the stratigraphic correlations, may be obtained if order is sent promptly to A.A.P.G. headquarters, Box 979, Tulsa, Oklahoma. Price per copy, folded in mailing envelope, postpaid: to A.A.P.G. members and associates, colleges, and libraries, $1.40; to others, $1.80. On orders for 100 or more, 10 per cent discount.

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1. Stanolind Oil and Gas Company Terry No. 1
2. W. A. Scott Keiser No. 1
3. Empire Gas and Fuel Company Russell No. 1-B
4. Welch *et al.* State No. 1
5. Western Drilling Company Green No. 2
6. Lockhart Root No. 2
7. Pueblo Russell No. 4
8. Skelly Lea No. 1
9. Maljamar Oil Company Miller No. 1
10. Henderson *et al.* Wyatt No. 1
11. Culbertson *et al.* State No. 1
12. Exploration Company Record No. 1
    Wells Nos. 11 and 12 are also shown on Woods cross section in this symposium.
13. Anderson & Pritchard Britt No. 1
14. Continental Oil Company Sophie Meyer No. 1
15. The Texas Company Alexander No. 1
16. Brown & Reynolds Parcell No. 1
17. Crafton Oil Company Richards & McWhorter No. 1
18. Stogner *et al.* Richards & McWhorter No. 1
19. Penn-Humble Wilson No. 1
20. Deep Rock *et al.* Kuykendall No. 1
    Well No. 20 is also shown on Fritz and FitzGerald's cross section in this symposium.
21. Honolulu-Llano Parker No. 1
22. Peters-Hargraves Riordan No. 1
23. Bond *et al.* McCarley No. 1
24. Green *et al.* Holt No. 1
25. Phillips Petroleum Company Slaughter No. 1
26. Humble Oil & Refining Company Slaughter No. 1
27. Magnolia Petroleum Company Slaughter No. 1
28. Westhyde Investment Company Looney No. 1
29. Moore Brothers Clayton-Johnson No. 1
30. Moncrief Munger No. 1
31. Julian Petroleum Company Long No. 1
32. Louisiana Oil & Refining Company Miller No. 1
33. Bristow & Cantrell Shannon No. 1
34. E. L. Smith Moore No. 1.
35. Dieckman & Pender Davis No. 1
36. Transcontinental Peckham No. 1
37. Forest Development Corporation Dry No. 1
38. Southern Oil Corporation Bacot No. 1
39. Southern Oil Corporation Robinson No. 1
    Wells Nos. 37 and 39 are also shown on Page and Adams' cross section in this symposium.
40. Merry Brothers & Perini Howard No. 1
41. Sinclair Oil & Gas Company Steele No. 1
42. Cranfill & Reynolds George No. 1

taken which is situated in the Back Reef zone well back of the Capitan Reef trend. On the west the first well of the section is the Stanolind Oil and Gas Company's Terry No. 1, on the west side of the Pecos River just north of Lake McMillan in Eddy County, New Mexico. This well begins in valley alluvium and caliche and then enters the Queen formation. Just east of this well, the Seven Rivers formation crops out along the east side of the Pecos River valley. Included with this Seven Rivers are undoubtedly parts of the Yates and Tansill formations, which have not been differentiated at the surface at this locality. The subsurface section can be considered, however, to be tied into the surface section at this point.

Eastward the section extends along the Artesia trend to the Maljamar field, whence it courses southeast across the San Simon syncline. It cuts diagonally across the Monument field and continues across the Central Basin platform in Andrews County, dropping off this feature just east of the town of Andrews. The section, then, continues due east across the Midland basin to central Martin County, where it veers northeast and maintains this general direction to the northeastern corner of Fisher County.

The area of outcrop of the Whitehorse group on the east side of the basin is crossed in eastern Scurry and western Fisher counties so that the subsurface section is considered to be tied into the surface in this locality.

The wells in this section were selected for their relative position and the character of each sample log. In all instances logs of cable-tool wells have been used. Since the logs on the geologic section were made from percentage logs and reduced one-half in the process, a certain amount of generalization and interpretation was necessary, but the logs are accurate down to an original 10-foot sample.

ACKNOWLEDGMENTS

The bulk of the data used in constructing this geologic section came from the files of the Stanolind Oil and Gas Company. In a larger sense this section is the result of the coöperative thinking of several geologists in an attempt to work out subsurface correlations in the upper Permian of the West Texas basin. Responsibility for all correlations and conclusions, however, rests with the writer.

Stratigraphy

The sediments encountered along the course of this geologic section range in age from upper Cambrian to Quaternary but since all but a few of the wells penetrate only to the top of the San Andres

the detailed discussion will be confined to the uppermost Permian. More specifically, the sediments from the top of the San Andres or "Blaine of Texas" to the base of the Triassic are the Permian rocks involved in nearly all the wells drilled in the West Texas Permian basin.

EAST SIDE

In Scurry and Fisher counties most of the wells have penetrated below the top of the San Andres and many have drilled below the San Andres. The Cranfill and Reynolds' George No. 1 in the Royston pool, the most easterly well on this geologic section, was drilled to a depth of 6,494 feet and completed in the San Saba formation of the upper Cambrian. All the divisions of the Pennsylvanian and Mississippian which are known on the Bend arch are present in this well with the exception of the Smithwick shale of the Bend group. In addition, according to Cheney,[4] the upper beds of the Ellenburger have been removed by truncation so that only a relatively thin Ellenburger section remains.

The division line between the Permian and Pennsylvanian is placed at the point of first appearance of the fusulinid genus *Schwagerina* in the section. *Schwagerina* was first found and reported from just below the Saddle Creek limestone in the Harpersville formation by R. I. Roth.[5] Since this horizon lies within the old "Cisco group," the Cisco series is now restricted to that portion which is Pennsylvanian and below the top of the Obregon formation.[6] It has been suggested by Cheney and others that all the sedimentary rocks between the top of his Obregon formation and the top of his Fisk formation, which is approximately 50 feet below the Elm Creek limestone, be grouped together as the Wolfcamp series. The finding by Scott and Plummer[7] and Miller[8] or a *Properrinites* ammonoid fauna from the "Indian Creek" shale near the top of the Fisk formation is a strong argument for such a series grouping.

Oil is being obtained in Fisher County from the Pueblo group of

[4] M. G. Cheney, personal communication.

[5] R. I. Roth, "New Information on the Base of the Permian in North Central Texas," *Jour. Paleon.*, Vol. 5, No. 3 (September, 1931), p. 295.

[6] M. G. Cheney, "Geology of North-Central Texas," in this symposium. The graphic cross section (well No. 42) follows the older nomenclature of Sellards *et al.*, "The Geology of Texas," Vol. I, *Univ. of Texas Bull. 3232* (1933).

[7] F. B. Plummer and Gayle Scott, "Geology of Texas, Vol. III, Upper Paleozoic Ammonites and Fusulinids, Pt. 1, Mississippian, Pennsylvanian and Permian Ammonites," *Univ. of Texas Bur. Econ. Geol. Bull. 3701* (1937), pp. 18, 19.

[8] A. K. Miller, "Comparison of Permian Ammonoid Zones of Soviet Russia with Those of North America," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 8 (August, 1938), p. 1017.

the Wolfcamp series in the Rotan pool and from the Obregon formation of the Cisco series in the Royston and Howard pools.

Cheney proposes to abandon the term *Wichita*. He places part of the old Wichita group in the Wolfcamp series and subdivides the part remaining in the Leonard series into three groups called, in ascending order, Belle Plains, Clyde, and Lueders. These three groups are not distinguishable in the subsurface of West Texas. Therefore the writer proposes to continue to use the term *Wichita group* (restricted) for the beds of Leonard age between the base of the Clear Fork group and the top of the Wolfcamp series.

The Wichita group (restricted) in Fisher County is about 800 feet thick from the top of the Lueders limestone to the top of the Fisk formation. Most of this section is limestone with some shale, and consequently it can not be readily divided into formational units in subsurface as at the surface on the east. One exception to this is the Belle Plains group which on the surface consists of the Bead Mountain limestone, Valera shale, Jagger Bend limestone, Elm Creek limestone, and Jim Ned shale. In the subsurface on the east side of the West Texas Permian basin below the Bead Mountain limestone this section consists of shale, gypsum, anhydrite, and dolomite.

The Clear Fork group on the surface consists of the Arroyo formation at the base, the Vale formation and the Choza formation. The Arroyo, which is about 250 feet thick, extends from the base of the Vale red shale to the top of the Lueders limestone and consists of green and gray shale, anhydrite, and dolomite. The Vale formation which, on the outcrop, consists of the Bullwagon dolomite at the top and about 350 feet of red shale below, grades westward in subsurface as a unit so that the thickness of the basal red shale becomes less and less while the amount of dolomite, gray shale, and anhydrite increases although the formation maintains its thickness of about 390 feet. The Choza exhibits the same gradation from an almost solid red shale section in Jones County to one of red, gray, and green shale, dolomite and anhydrite in western Fisher County to one of almost solid dolomite in western Scurry County. At the base of the Choza is a section of about 50 feet of clastic material consisting of red shale and red sand. This clastic section can be traced in subsurface north and south along the east side and even westward where most of the Clear Fork is all dolomite.

SAN ANDRES "BLAINE OF TEXAS" PROBLEM

At the end of Clear Fork-Yeso time the southeastern and northwestern rims of the basin were evidently elevated so that San Andres time was inaugurated with an influx of clastic material in these areas

which material is known as the San Angelo and the Glorieta in the respective areas. This clastic material is coarse on the margins of the basin, particularly the southeastern margin, but it becomes finer toward the center until in the interior of the basin there is but little evidence of a break between the Clear Fork and the San Andres.

The "Blaine of Texas" is herein called the San Andres because it is believed that the unconformity at the top of the Dog Creek shale on the east side of the basin can be tied into the top of the San Andres on the west side of the basin by means of well logs. This correlation was suggested by Willis[9] and others in 1929. The San Andres on the east side can be divided into the Dog Creek shale, the Blaine gypsum and the Flower-pot shale, a division which has been known in Oklahoma for some time. The top of the Dog Creek shale is there called the top of the El Reno group.

The term San Andres as used on the west side of the basin at the present time includes those beds between the base of the Whitehorse group and the top of the Yeso. In the Guadalupes, measurement of the San Andres has shown it to be about 1,250 feet thick, and in wells in the basin it reaches a thickness of about 1,460 feet. It has been assumed that this entire thickness is San Andres in age. At its type locality in the San Andres Mountains, the San Andres is 500 feet thick[10] and contains fossils which suggest its correlation with the Leonard of the Glass Mountains of Texas. At its type locality the base is exposed but the top of the San Andres passes under the alluvium of the Jornado del Muerto.

There is certain evidence that the increased thickness of the so-called San Andres in the Guadalupes and in subsurface is due to the fact that the additional section is younger than the San Andres at the type locality. This implies a division within the so-called San Andres dividing that portion of the section which is Leonard in age and which corresponds to the San Andres as originally defined from the younger beds which are probably middle Delaware Mountain in age. In the Guadalupe Mountains the uppermost beds of the so-called San Andres have been traced southward into beds which Lang[11] has

[9] Robin Willis, "Preliminary Correlation of the Texas and New Mexico Permian," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 8 (August, 1929), p. 1012.

[10] Willis T. Lee, "The Manzano Group of the Rio Grande Valley, New Mexico," *U. S. Geol. Survey Bull. 389* (1909), pp. 12, 14, and 29.

[11] Walter B. Lang, "The Permian Formations of the Pecos Valley of New Mexico and Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 7 (July, 1937), p. 858.

Many geologists will disagree with Dickey's statement that the so-called San Andres of the Guadalupe Mountains has been traced southward into beds which Lang has called Dog Canyon. Correlations between the northern and southern Guadalupe Mountains are still uncertain but it is hoped that work by the United States Geological Survey in the next few years will clear up these uncertainties.—Editorial note.

called Dog Canyon. The definition of the Dog Canyon is very unsatisfactory in that it does not give the upper and lower limits of the formation nor the thickness at any one place. The important facts are that these beds contain fusulinids which are of middle Delaware Mountain age and that the beds themselves can be traced southward into middle Delaware Mountain sand. Furthermore, on the Central Basin platform and in the southern part of the basin fusulinids of middle Delaware Mountain age are found in the so-called San Andres below the Whitehorse group.[12]

WHITEHORSE GROUP

The Whitehorse is here used as a "group" term and includes the following formations, beginning with the oldest: Grayburg, Queen, Seven Rivers, Yates, and Tansill. It is not contended here that these formations in the Whitehorse group can be sharply differentiated as to their upper and lower limits in all wells in the West Texas Permian basin. It is believed, however, that these formations can be recognized in subsurface by their contrasting lithologies. For example the Tansill formation is essentially one of chemical deposits while the underlying Yates sand formation is essentially a clastic deposit with minor amounts of anhydrite and salt beds. The Seven Rivers is a formation consisting primarily of dolomite, anhydrite, and salt while the underlying Queen formation is one containing much sand. The oldest formation in the Whitehorse group, the Grayburg, contains more dolomite beds than the others along with sand and anhydrite. It is these lithological units, chemical against clastic, one succeeding the other, which can be correlated in subsurface across the West Texas-New Mexico Permian basin. It is recognized that the structural features which existed at the time of the deposition of these formations influenced the composition of the deposits. For example, other geologic sections have shown that these formations as they approach the Capitan reef grade gradually into a section of solid dolomite where differentiation is impossible. On a smaller scale the central part of the Central Basin platform received much less clastic material than the edges, and the adjoining basins received more clastic and evaporite deposits than the Central Basin platform. The five units as named above can be traced, however, across all these structural features.

Grayburg formation.—The initial beds of the Whitehorse group, being of great economic importance in the Permian basin, are here

[12] J. W. Skinner, personal communication. With further refinements in correlation these beds containing middle Delaware Mountain fusulinids may prove to be post-San Andres in age.—Editorial note.

given the name Grayburg and are defined from the section as exposed in well No. 6 of the cross section, Cecil H. Lockhart's Root Permit No. 2 in the center of the SW. ¼, SW.¼ of Sec. 7, T. 17 S., R. 30 E., Eddy County, New Mexico, drilled with cable tools. The elevation of the derrick floor was 3,661 feet above sea-level; the total depth was 3,763 feet, completed in November, 1933, plugged, and abandoned. The name is taken from the Grayburg pool which lies one mile south of the Root well. The beds which are herein called Grayburg undoubtedly crop out in the Guadalupe Mountain area west of Carlsbad, and at some future time they should be measured and defined in this area. Lang[13] referred to beds which seem to occupy the same position as the Grayburg as possible Dog Canyon, correlating them with a much thicker Dog Canyon section on the west side of the Guadalupes, but this can not be definitely proved nor did Lang define them as to their upper and lower limits. The Dog Canyon beds of Lang contain fusulinids of middle Delaware age according to Skinner.[14]

The samples from which the following description of the Grayburg formation was made are on file in the Stanolind Oil and Gas Company office at Midland, Texas, and in a number of other oil company offices in the area.

Sample Description of Grayburg Formation in Cecil H. Lockhart's Root Permit, No. 2, Sec. 7, T. 17 S., R. 3 E., Eddy County, New Mexico.

Depth in Feet	*Per Cent*	*Description*
		QUEEN FORMATION
2,300–2,325	30	white finely crystalline anhydrite
	70	fine-grained orange-red sand
–2,350	10	white finely crystalline anhydrite
	50	reddish brown dense anhydrite
	40	fine-grained orange-red sand
–2,375	45	white dense anhydrite
	45	reddish brown dense anhydrite
	7	fine-grained orange-red sand
	3	red shale
		GRAYBURG FORMATION
–2,380	15	pink very finely crystalline dolomite
	85	light brownish gray finely crystalline dolomite
		trace of anhydrite
–2,400	10	light brownish gray dolomite
	40	white crystalline anhydrite
	20	reddish brown dense anhydrite
	30	fine-grained orange-red sand
		trace of red shale
–2,420	75	sandy pink, reddish brown and light gray dolomite
	5	white crystalline anhydrite
	20	fine orange-red sand

[13] W. B. Lang, *op. cit.*, pp. 858, 859.

[14] J. W. Skinner, personal communication.

−2,435	10	pink dolomite with inclusions of anhydrite crystals
	85	white dense dolomite with inclusions of anhydrite crystals
	5	fine orange-red sand
		trace of red shale
−2,450	100	light gray very finely crystalline dolomite with inclusions of anhydrite crystals
		trace of selenite
−2,460	100	light gray dense dolomite with inclusions of anhydrite crystals
−2,470	100	light gray finely crystalline with inclusions of anhydrite crystals
−2,480	100	brownish gray finely crystalline dolomite
−2,495	20	light gray finely crystalline dolomite
	68	reddish brown dense dolomite
	10	white crystalline anhydrite
	2	fine-grained brownish red sand
−2,504	50	light gray and pink and lavender dense dolomite
	30	white coarsely crystalline anhydrite
	20	fine-grained gray anhydritic sand
−2,525	88	slightly sandy gray dense dolomite
	10	slightly sandy pink dense dolomite
	2	fine dark red sand
		trace of dark red shale
−2,530	100	white finely crystalline dolomite with inclusions of anhydrite crystals
−2,545	100	white finely crystalline dolomite with inclusions of anhydrite crystals
−2,555	100	light gray dense dolomite
−2,565	60	buff dense dolomite with inclusions of anhydrite crystals
	40	fine gray sand, light oil stain
−2,570	85	light gray dense dolomite
	5	selenite
	10	fine-grained gray sand
−2,585	100	buff finely crystalline dolomite
−2,595	90	buff finely crystalline dolomite
	10	pink finely crystalline dolomite
−2,601	95	buff finely crystalline dolomite
	5	selenite
−2,608	20	buff finely crystalline dolomite
	80	fine-grained gray sand. Sand contains frosted quartz grains. Light oil stain
−2,614	20	buff finely crystalline dolomite
	80	fine-grained gray sand
−2,620	100	buff finely crystalline dolomite
−2,630	70	buff crystalline dolomite
	30	fine loose clear quartz sand
−2,632	100	buff finely crystalline dolomite
−2,639	20	gray and brownish red dense dolomite
	80	very fine-grained brownish red sand
−2,647	70	sandy brownish red dense dolomite
	30	very fine brownish red sand
		trace of dark red shale
−2,655	100	brownish red and light gray dense dolomite
−2,661	50	buff dense dolomite, oil stains
	50	fine-grained clear quartz sand, oil stain
−2,668	50	buff dense dolomite
	50	fine-grained clear loose quartz sand
−2,674	70	buff dense dolomite
	30	fine-grained clear loose quartz sand

SAN ANDRES FORMATION

−2,679	100	white crystalline dolomite, oil-stained
−2,685	100	white crystalline dolomite, oil-stained
−2,690	100	white crystalline dolomite, oil-stained
−2,695	100	buff crystalline dolomite, oil-stained

As shown on the geologic section the Grayburg formation can be traced from Eddy County, New Mexico, across the Central Basin platform and the Midland basin and eastward where it becomes primarily clastic and merges with the clastic Whitehorse section on the outcrop in Fisher County. The Grayburg formation is overlain conformably by the Queen formation which is made up essentially of clastic material and it overlies unconformably the dolomites and limestones of the San Andres. The composition of the Grayburg formation itself varies considerably throughout the southern Permian basin as do all of the formations of the Whitehorse. It is characterized, however, by a predominance of dolomite beds which vary in color from gray to pink and white. These dolomite beds are locally sandy and interbedded with gray and red sands which in many places carry the frosted quartz grains characteristic of upper Permian sediments. In addition to dolomite and sand, beds of anhydrite are present particularly in structurally lower areas, and also beds of sandy gray shale and gray and green bentonite. The Grayburg formation is not of a constant thickness, resting as it does on the pronounced unconformity at the top of the San Andres. This unconformity has been adequately described and traced for the east side of the Permian basin by Robert Roth.[15] The thickness averages close to 300 feet as far east as central Borden County and from there eastward thins considerably. On the surface on the east side the Grayburg may be represented by the Eskota dolomite and the orange-red sand between it and the underlying Dog Creek shale.

The Grayburg formation has yielded oil in most fields on the eastern edge of the Central Basin platform from Yates as far north as the North Cowden field, and produces in the Eunice and Monument fields of Lea County, New Mexico.

Queen formation.—The Queen sandstone member of the Chalk Bluff formation as defined by Lang[16] includes approximately 100 feet of "white, buff to pinkish colored fine-grained sandstone" interbedded with inorganic limestones. Blanchard and Davis,[17] however, give the thickness of their "Queen sand zone" as ranging from 0 to 500 feet which thickness corresponds better with the known sand section in the subsurface. In Eddy County, New Mexico, in the subsurface, the top of the Queen formation is placed at the top of the "Red sand" of Artesia, a prominent marker as far east as the Texas State line. The

[15] R. Roth, "Custer Formation of Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 4 (April, 1937), pp. 421–79.

[16] W. B. Lang, *op. cit.*, p. 859.

[17] W. A. Blanchard and M. J. Davis, "Permian Stratigraphy and Structure of Parts of Southeastern New Mexico and Southwestern Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 8 (August, 1929), pp. 972, 983, 987.

Queen is about 350 feet thick in this area. On the east side in Borden and Scurry counties in subsurface the top is placed at the base of a prominent salt section, and here it consists largely of orange-red sand. On the Central Basin platform there is very little sand in the Queen formation. This formation produces oil in a belt paralleling the Capitan reef from Pecos County to Eunice, New Mexico, and in Eddy County, New Mexico, the sands being locally known as the "Shipley," "Colby," "Penrose," "Shugart," *et cetera.*

Seven Rivers formation.—The Seven Rivers gypsiferous member of the Chupadera formation was defined by Meinzer, Renick, and Bryan[18] as being "100 feet or more of gypsiferous beds." Lang[19] refers to the Seven Rivers gypsiferous member of his Chalk Bluff formation as a

> series of sandstones, anhydritic sandstones, and redbeds, with intercalated anhydrite and thin dolomitic limestones from an inch to a few feet in thickness [which] lies above the Queen sandstone and is capped by a thin tongue of Carlsbad limestone . . . .

Lang does not mention any thickness for this member. In the subsurface the top is placed at the base of the Yates sand section and the base at the top of the Queen sand section. The top is commonly marked by a thin bed of brown dolomite in Eddy and Lea counties, New Mexico. The Seven Rivers formation in subsurface in New Mexico and on the Central Basin platform consists essentially of anhydrite and brown dolomite. Farther east salt beds come into the section and in the Midland basin and eastward to Scurry County the Seven Rivers formation is one of almost solid salt. On the outcrop in eastern Scurry it is represented by orange-red sand, the salt being absent probably by solution. The thickness of the Seven Rivers across the basin averages about 500 feet.

Yates sand.—At its type locality in the Yates field, the Yates sand consists of 50 feet of sand with some anhydrite. Along the line of this geologic section, the Yates sand section is much thicker and the actual amount of sand present varies greatly. It averages about 250–300 feet in thickness for the Central Basin platform and Midland basin and contains in addition to sand, beds of red shale, anhydrite, and dolomite. On the east side the Yates thins to about 150 feet in Scurry County. It is known to crop out in the vicinity of Carlsbad south of the western terminus of this section and is probably

[18] Meinzer, Renick and Bryan, "Geology of No. 3 Reservoir Site of the Carlsbad Irrigation Project, New Mexico, with Respect to Water Tightness," *U. S. Geol. Survey Water-Supply Paper 580-A* (1926), p. 13.

[19] W. B. Lang, *op. cit.*, p. 860.

present in western Fisher County, overlying the Sweetwater dolomite. The widespread occurrence of the Yates and the presence of large well rounded and frosted quartz grains near the top of the sand have led to the use of this formation as a marker on which to map the subsurface structure of the West Texas Permian basin. Along the east side of the Capitan reef where the section is becoming increasingly dolomitic, the Yates sand is present in the dolomite, and oil is obtained from the sand from Pecos County, Texas, to southern Lea County in New Mexico.

Tansill formation.—The youngest formation in the Whitehorse group in the West Texas Permian basin has been defined on the surface in the Carlsbad area by DeFord *et al.*[20] In the subsurface in this section the Tansill is represented by those beds which lie between the base of the Upper Castile and the top of the Yates sand. It is a formation composed essentially of evaporites with dolomite predominating in the areas adjacent to the Capitan reef and anhydrite predominating in areas removed from the reef. The Tansill has a thickness of about 150–200 feet on the west in Eddy County and thins gradually eastward until in eastern Scurry County the Tansill consists of a bed of anhydrite and bed of salt with a total thickness of 50 feet.

Upper Castile formation.—As shown on the geologic section, the Upper Castile has its greatest thickness in the Midland basin and in the San Simon syncline. It thins over the Central Basin platform, and disappears before reaching the surface on either side of the basin. The base is marked by an unconformity which is commonly represented in subsurface by a bed of red shale or red sand and which is interpreted as representing the interval during which the Lower Castile was being deposited in the Delaware basin. On the east side of the basin some of the orange-red sand at the top of the section may be equivalent to the Upper Castile, but it is known that the Upper Castile thins considerably in western Fisher County so that it may be entirely overlapped by the Dewey Lake formation.

There are several anhydrite, polyhalite and sand beds in the Upper Castile salt section, but the most widespread one is the Cowden anhydrite member.[21] This member is a dolomitic anhydrite which becomes nearly all dolomite on the edges of the basin and which lies 150–200 feet above the base of the Upper Castile. It is a very widespread bed, being present in nearly all parts of the basin.

Rustler formation.—Overlying the Upper Castile salt section with

[20] R. K. DeFord and others, in a forthcoming paper.

[21] Defined by Sam C. Giesey and Frank F. Fulk, "North Cowden Field, Ector County, Texas," a forthcoming paper.

an angular unconformity is the Rustler formation which represents the last invasion of the West Texas Permian basin by marine waters. On the west end of this geologic section it consists of 300$\pm$ feet of dolomite, anhydrite, a few salt beds, shale, and sand. The top of the Rustler formation is an erosion surface on which the Dewey Lake sands have been deposited. The formation thins eastward until in eastern Borden County it is represented by only a thin bed of anhydrite or sand.

Dewey Lake formation.—The youngest Permian formation on this section is the Dewey Lake,[22] a section of orange-red sand similar to the underlying Whitehorse sands. It is overlapped on the west in the vicinity of the west line of Lea County by the Tecovas shale of the Triassic and is also possibly overlapped on the east side as well. If it does crop out on the east side, the Dewey Lake is probably indistinguishable from the remaining Whitehorse sand section along the outcrop.

TRIASSIC

The Upper Triassic in the West Texas Permian basin is represented by the Docum group which consists of the Chinle, Santa Rosa and Tecovas formations. These formations are thickest along the line of this section in the deepest part of the Midland basin where the Docum group is approximately 1,700 feet thick. The Tecovas shale is overlapped on the east by the Santa Rosa sandstone in the vicinity of the eastern Borden County line and on the west in the vicinity of the western Lea County line. The Santa Rosa is a sand or conglomerate which varies considerably in thickness, but is widespread, covering most of the basin and cropping out on the east side in eastern Scurry

[22] Lincoln R. Page and John Emery Adams, "Stratigraphy, Eastern Midland Basin, Texas," p. 55, this symposium.

Page and Adams say that the Dewey Lake and Rustler are conformable. They and other geologists will disagree with Dickey's statement that the top of the Rustler is an erosional surface on which the Dewey Lake sands were deposited. The argument is about as follows.

The uniform thickness of the higher Rustler beds where Dewey Lake redbeds are present and the sanding up of the upper evaporites in the northern and eastern parts of the Midland basin suggest that the contact is gradational rather than unconformable. Where the Dewey Lake beds have been removed by post-Permian erosion, the Tecovas or young Triassic beds rest on the eroded surface of the Rustler or older Permian formations.

If the Rustler-Dewey Lake contact is conformable, the Dewey Lake sands should, if exposed in the eastern outcrops, be separated from the underlying outcrops of Whitehorse sand by the Rustler evaporites. It is possible that much of the confusion about the presence of Dewey Lake redbeds in the eastern outcrops is due to the cropping out of fine-grained Tecovas silts and sands that are incompletely overlapped by the Santa Rosa conglomerates, as Dickey suggests. The same statement may apply to the western areas, beyond the limits of the Santa Rosa, where outcrops of Tecovas sands and silts cover hundreds of square miles in the valleys of the Pecos and Canadian rivers.—Editorial note.

County. The Chinle is a thick section of red shales with some fresh-water limestones and green shales.

POST-TRIASSIC SEDIMENTS

Overlying the Triassic are beds ranging in age from Comanche to Recent. Over the greater part of the Llano Estacado along the line of this section is a thin section of Comanchean consisting of "Basement" sand and Edwards limestone. Overlying the Comanche are sediments of Pliocene age which belong to the Ogallala formation. In many places on the south these have been removed or were never deposited. They consist of sands and gravel, and east of the Llano Estacado they rest directly on the Triassic. In the Pecos River valley and along the eastern margin of the Llano Estacado are beds of Pleistocene age which represent debris which was deposited at some stage after the Llano Estacado had been subjected to erosion. The youngest beds along the section are those caliche beds which have formed by the calcification and silicification of the top part of the Ogallala beds in comparatively recent time.

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STRATIGRAPHY, EASTERN MIDLAND BASIN, TEXAS[1]

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ABSTRACT

The thick series of redbeds along the eastern edge of the southern Permian basin is divided into groups and formations that can be recognized both on the outcrops and in the subsurface. Gradations between nearshore, marine, and retricted sea deposits are recognized and described, and unconformities in the section are traced out into the basin. The Triassic-Permian boundary line is re-defined as occurring between the top of the newly defined Dewey Lake redbeds and the base of the overlying Tecovas silts.

INTRODUCTION

Correlation of the formations encountered in wells in the eastern Permian basin with the eastern outcrops and with the stratigraphic section of other areas within the basin has been developed sufficiently for the various groups and formations to be recognized and named in the subsurface. In presenting these data as an aid to future workers a cross section was selected to show the stratigraphic relationships. Twenty-seven cable-tool wells from which cuttings have been microscopically examined furnish the basis for the graphic illustrations. As shown on the accompanying map (Fig. 1), the section extends from Merry Brothers and Perini's Williams No. 1 in northeastern Stonewall County southwestward through Fisher,[4] Scurry, and Mitchell counties to the Continental's Brice No. 1 in southwestern Howard County, and from there southward through Glasscock and Reagan counties to the Stanolind's Todd No. 1 in Crockett County. In reality, the cross section consists of two sections extending from the marginal areas at the ends toward the center of the Midland basin. Graphic lithology is based on sample examination. Where samples were not available, drillers' logs were used to pick stratigraphic contacts, but lithologic determinations from this source were not plotted.

ACKNOWLEDGMENTS

The data used have been taken from the files of the Standard Oil Company of Texas. Many of the ideas have been taken entirely from

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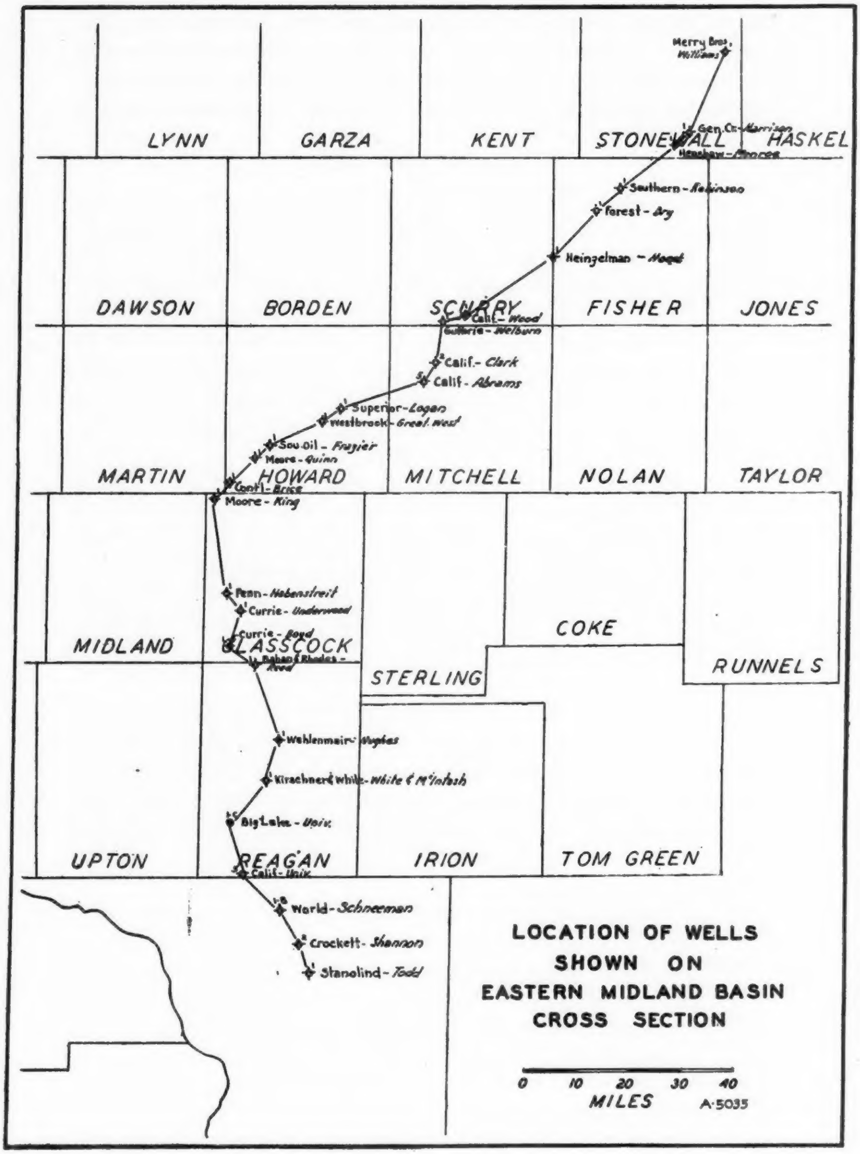
[3] Standard Oil Company of Texas.

[4] Two wells in Fisher County are common to Dickey's and Page and Adams' cross sections: Forest Development Corp. Dry No. 1 and Southern Oil Corp. Robinson No. 1. —Editorial note.



LYNN
GARZA
KENT
STONEWALL
HASKEL
DAWSON
BORDEN
SCURRY
FISHER
JONES
MARTIN
HOWARD
MITCHELL
NOLAN
TAYLOR
MIDLAND
GLASSCOCK
COKE
STERLING
RUNNELS
UPTON
REAGAN
IRION
TOM GREEN
Merry Bros. Williams
Gen. Cr.-Harrison
Henshaw-Moores
Southern-Robinson
Forest-Bry
Heinzelman-Magel
Calif.-Wood
Guthrie-Welburn
Calif.-Clark
Calif.-Abrams
Superior-Logan
Westbrook-Great West
Sou. Oil-Frazier
Moore-Quinn
Cont'l-Brice
Moore-King
Penn-Hobenstreit
Currie-Underwood
Currie-Boyd
Wohlenmeir-Hughes
Kirschner & White-White & McIntosh
Big Lake-Univ.
Calif.-Univ.
World-Schneeman
Crockett-Shannon
Stanolind-Todd
LOCATION OF WELLS
SHOWN ON
EASTERN MIDLAND BASIN
CROSS SECTION
0
10
20
30
40
MILES
A-5035

FIG. 1

one or another of the hundreds of geologists who have worked in the area but the writers assume responsibility for all correlations and interpretations. The stratigraphic terminology is that selected by a committee of local geologists for use in the present series of Permian papers.

General Structure

The three major structural features of the southern Permian basin are the Delaware and Midland basins and the Central Basin platform. The lateral basins were negative elements in which almost continuous subsidence and sedimentation occurred throughout Permian time. Until late in its history, the Midland basin was an isolated depression connected with the Delaware basin and the open sea on the west by east-west channel-ways around the ends of the Central Basin platform. About the beginning of Upper Castile salt deposition the Central Basin platform lost its positive dominance, the lateral basins grew together, and the entire area acted as a single unit.

The regional west dip on the east side of the Midland basin is complicated by pronounced east-west structural trends such as the Concho and Red River arches and the Stonewall syncline. Small, limited structures such as those of the oil fields have been developed on the broader features as a result of irregular sedimentation, compaction of sediments, and gentle regional stresses. Both the major and minor structures have influenced the stratigraphy.

Stratigraphy

The entire stratigraphic section above the top of the Wichita-Albany group is discussed in the eastern area, while farther west and south only the post-San Andres sediments are considered. The nomenclature used is of composite origin. Names of the Wichita and Clare Fork group are used as defined in Volume I of the "Geology of Texas."[5]

The type section of the San Andres group is in the San Andres Mountains of central New Mexico. The group has been recognized with its present limits for many years by subsurface geologists. As used here, it includes the San Angelo and the "Blaine of Texas." The four formations from the bottom upward are San Angelo, Flowerpot, Blaine, and Dog Creek. The only one of these widely recognized by subsurface geologists is the San Angelo sandstone.

The top of the San Andres is overlapped by sediments which are correlated with the Delaware Mountain group. In the eastern Midland basin where only the Middle and Upper Delaware Mountain

[5] E. H. Sellards *et al.*,"Geology of Texas, Vol. 1," *Univ. of Texas Bull. 3232* (1932).

section is present, these beds are included in the Whitehorse group. Whitehorse is a Kansas-Oklahoma name, including the Marlow, Rush Springs, and Cloud Chief formations. In Texas, where a more complete Permian section is present, the group is extended upward and downward to include the entire evaporite section between the post-San Andres and pre-Castile unconformities.

Whitehorse formations from the bottom upward are Grayburg, Queen, Seven Rivers, Yates, and Tansill. The Grayburg is a subsurface formation named and described in this series of papers by R. I. Dickey. The Queen, Seven Rivers, and Tansill formations are exposed in New Mexico. The Yates sand is a subsurface formation named in the Yates field where it occurs approximately 500 feet above the main Yates limestone pay zone.

The upper Permian group includes the Castile, Rustler, and Dewey Lake formations. The first two crop out along the western margin of the Permian basin. The Dewey Lake formation is named and described in this paper.

Above the Permian is the Dockum group of Upper Triassic age. The three formations into which the group is divided are from the bottom upward: Tecovas from the Texas Panhandle; Santa Rosa from eastern New Mexico; and Chinle from Arizona. Cretaceous formations were all named in Texas. The accompanying cross section (Fig. 2) shows the distribution, lithology, and structural relationships of these formations in wells in the eastern Midland basin.

PERMIAN SYSTEM

The Permian formations were laid down in a restricted sea which was retreating southward during Permian time. Near shore the section is composed dominantly of red clastics with interbedded evaporites. Wedges of the clastics extend far out into the basin and furnish important stratigraphic markers. In the intermediate areas evaporites predominate. Clastics in this zone in the lower beds are green or gray. Still farther out, marine limestones and dolomites predominate. In the area crossed by the section, the marine beds range upward into the lower Whitehorse and for these beds all three zones are present. From the top of the Tansill to the top of the Rustler only the onshore and intermediate zones are present. The Dewey Lake at the top represents the final retreat of the Permian sea and the filling in of the basin with red sands.

The processes described were carried on in spite of the marked unconformities between the San Andres and the Whitehorse, the Whitehorse and Upper Castile, and between the Upper Castile and the Rustler groups. The San Andres-Whitehorse disconformity is

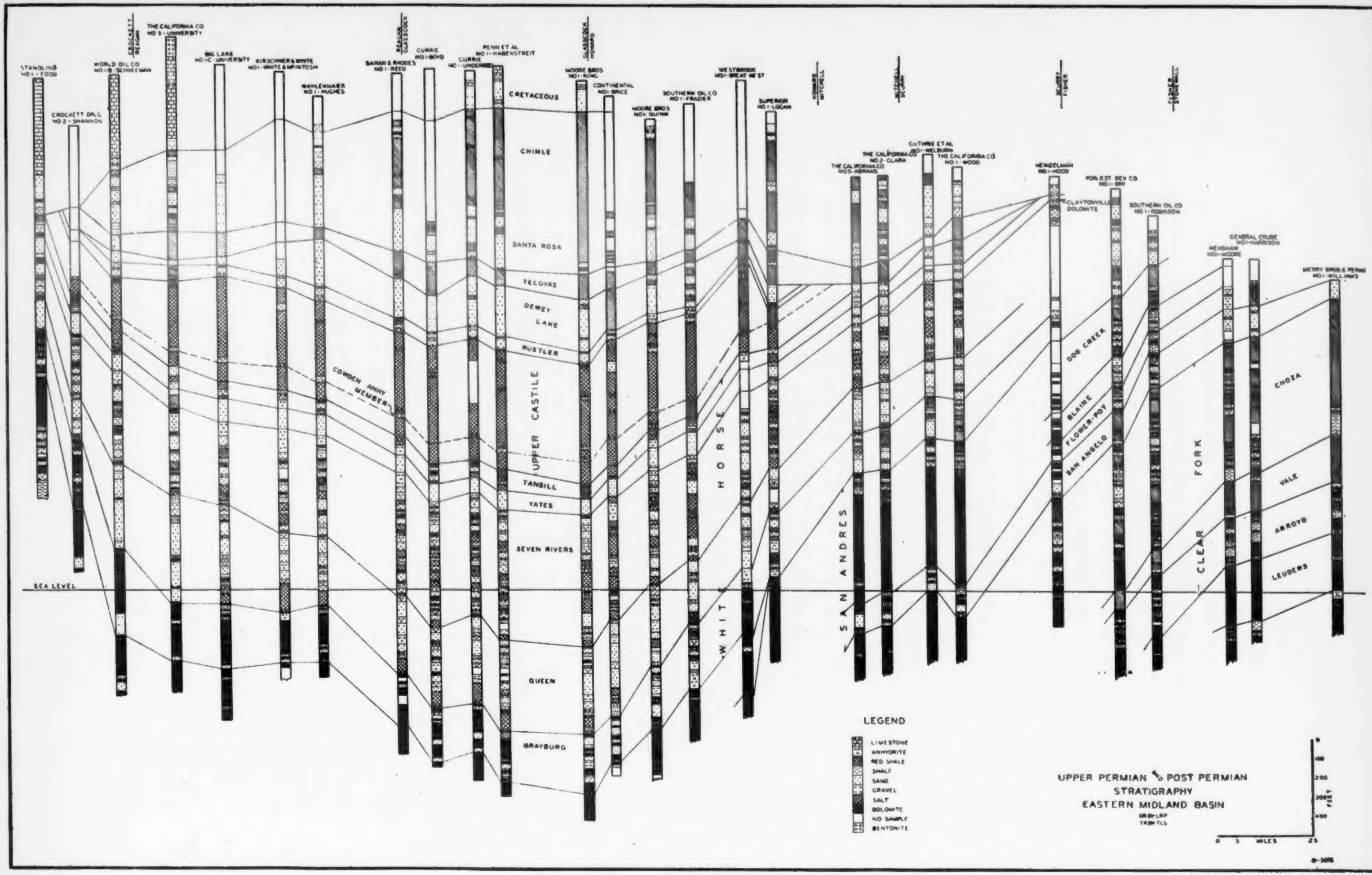


FIG. 2. Cross section, eastern Midland basin.

NOTICE.—A large blue-line paper print of Figure 2, on a sheet approximately 36×24 inches, may be obtained if order is sent promptly to A.A.P.G. headquarters, Box 979, Tulsa, Oklahoma. Price per copy, folded in mailing envelope, postpaid: to A.A.P.G. members and associates, colleges, and libraries, $0.70; to others, $0.85. On orders for 100 or more, 10 per cent discount.

much more pronounced in the marginal areas than in the center of the basin where the older sediments were protected from erosion and beds not present in the marginal sections were deposited. The upper unconformities are recognized within the basin proper.

CLEAR FORK GROUP

The Clear Fork group, in outcrop, is predominantly red to brownish red shale with seams and beds of white gypsum. Locally a few interbedded white to gray dolomite lenses and reddish sandy zones are present. In subsurface, at Merry Brothers and Perini's Williams No. 1 in Stonewall County, dolomite beds are prominent in the lower portion, the Arroyo formation. As the group is traced westward the dolomites become progressively more important at the expense of the shales until, in Heinzelman's Hood No. 1, Scurry County, the section is predominantly dolomite with only minor anhydrite beds. From this well westward it is nearly impossible to recognize the various divisions of this group. The thickness indicated in the section is 1,100–1,300 feet.

Arroyo formation.—At the base of the Clear Fork group are 225–300 feet of interbedded shales, anhydrite, and dolomite, known as the Arroyo formation. The red shales of the eastern portion grade within a short distance westward into gray shales, anhydrite, and dolomite.

Vale formation.—The Vale formation on the outcrop consists of red-brown shale which persists as far west as Scurry County, where it grades into dolomite. The gradational thinning of this shale member westward is abrupt, for in Merry Brothers and Perini's Williams No. 1 it shows a thickness of 250 feet as compared with 100 feet in the Forest Development Corporation's Dry No. 1.

Choza formation.—In Merry Brothers and Perini's Williams No. 1, the Choza formation consists of 825–850 feet of red-brown shales with a few thin dolomites near the top and minor sand stringers near the base. Toward the south and west, the sandstones increase in number and importance, especially in the upper beds, until it is difficult in some areas to pick the San Angelo-Choza contact. West of central Stonewall County the red shales grade basinward into gray shales, these into anhydrite, and the anhydrite into dolomite. Thus samples from Heinzelman's Hood No. 1, Scurry County, show that the red shales have disappeared and that gray shales and anhydrite predominate. On the southwest, in the California's Wood No. 1, Scurry County, the section is almost entirely dolomite.

SAN ANDRES GROUP

In the eastern outcrops the San Andres formations consist mostly of clastics. Gypsum and dolomite beds, many with local names, are much more prominent than in the shales of the underlying Clear

Fork group. Traced westward into the subsurface, the shales and evaporites are replaced by dolomites.

San Angelo sandstone.—Near San Angelo in Tom Green County, a deltaic accumulation of conglomerates and sandstones occupies almost the entire San Andres interval. Away from this center, the upper sandstones grade laterally into shales and downdip into limestones and dolomites. The basal member persists as a sandstone over wide areas. It is this bed to which the name San Angelo is restricted away from the type locality.

On the outcrop, in Stonewall County, the formation is a medium- to fine-grained red and gray sandstone with intercalated shale members. No conglomerate is present this far north. In the subsurface, the thickness varies from 120 to 175 feet along the line of the section with the structurally high areas showing a noticeable thinning. The sandstones grade basinward into silts and exceedingly fine-grained sandy dolomites.

In the northern, shallower portions of the South Permian basin, the San Angelo can be traced westward in the subsurface to correlate with the Glorieta sandstone of New Mexico. It is probable, however, that the importance of the unconformity at the base of the San Angelo formation has been greatly over-estimated.

Flower-pot shales.—In Stonewall County, the gray shales and thin dolomites noted in subsurface, above the San Angelo sandstone, are equivalent to the red-brown shales recognized in outcrop as the Flower-pot shales. Thickness up to 120 feet has been recorded in the subsurface. Lateral gradation causes the distinctive red-brown color recognized at the surface to disappear and, in Scurry County, wells cut solid dolomite in this section.

Blaine gypsums.—The Blaine gypsums, easily identified on the outcrop as interbedded gypsums, with a few red sandstone lenses, and reddish shales, lie between the dolomites and red-brown shales of the Dog Creek and the red-brown shales of the Flower-pot. The exposed gypsums pass into anhydrite in subsurface and thence into dolomite, while the accompanying red-brown shales grade into gray shales and anhydrite and finally into dolomite. In Scurry County, the equivalent section, as in the case of the Clear Fork formations, is a dolomite.

Dog Creek shales.—The dolomites and red-brown shales above the Blaine gypsums grade down dip into anhydrites and dolomites. The shales in this zone are more persistent than the underlying clastic beds and suggest a change from the widespread chemical sedimentation of the Blaine gypsums. Probably the sea level was lowered and shale deposition extended farther out into the Midland basin than

during the earlier Blaine time. Middle Dog Creek dolomites cropping out in Kent County contain a *Perrinites*, ammonite, fauna of Leonard age, thus linking the eastern outcrops and the Permian section of the Glass Mountains.

The Flower-pot, Blaine, and Dog Creek formations have in the past been grouped together to form the "Blaine of Texas."

WHITEHORSE GROUP

The term Whitehorse group is here used to designate all the eastern equivalents of the Delaware Mountain group. On the eastern outcrops and in central Crockett County, Whitehorse beds rest unconformably on various members of the San Andres group. Westward in the subsurface successively older beds come in above the unconformity at the base of the exposed section. The outcrop section is characterized by very fine orange-red sandstone with scattered frosted quartz grains and interbedded evaporites. Within the limits of the southern Permian basin, the entire Whitehorse evaporite section grades westward and southward into fossiliferous Permian limestones. The separation of the Whitehorse group into five formations along the line of the section is based primarily upon sedimentary characteristics that reflect changes in environment of deposition. The changes in lithology on which this correlation is based can be recognized throughout the southern Permian basin in the subsurface and on the outcrops in New Mexico, but they have not been distinguished on the eastern outcrops or in the Panhandle district.

Grayburg formation.—The Grayburg beds include that portion of the Whitehorse group between the thin dolomites recognized in the subsurface just below the lowermost salt of the Queen formation and the unconformity at the top of the Dog Creek shales. In the northern areas, the Grayburg is characterized by the presence of fine orange-red and gray sandstones which contrast sharply with the shales of the underlying Dog Creek. Coarse frosted grains, so characteristic of other portions of the Whitehorse, are conspicuous by their absence. Interbedded with the sands are red-brown shales, anhydrite, buff dolomite, and thin beds of salt. In most wells there is a thin bed of bentonite at or near the base.

South of central Glasscock County the proportions of dolomite increase at the expense of the anhydrite. The sands associated with the dolomite are gray, whereas the same sands associated with anhydrite and salt are orange-red in color. In southern Reagan County the dolomites give way to limestones that contain an abundant *Parafusulina* fauna of middle Delaware Mountain age. Still farther south, in Crockett County, the limestones are replaced by sands, shales, and conglomerates of a nearshore facies.

The sandstones, shales, and conglomerates in Crockett County are basal beds above an unconformity and apparently represent outwash from an area of considerable uplift. At the northern end of the section this unconformity, which on the outcrop cuts out most of the San Andres section, is responsible for the marked thinning of the underlying Dog Creek section between the Forest's Dry No. 1 and the Southern's Robinson No. 1.

The Grayburg is the least extensive of the Whitehorse formations discussed in this paper, being fully developed only in the lower parts of the basin. In western Howard, Glasscock, and Reagan counties, still older members of the Whitehorse are present but due to the limited number of wells the stratigraphy is not well understood. The Grayburg formation is included as a member of the Whitehorse group because it is separated from the underlying San Andres beds by an angular unconformity and because it contains sands that are indistinguishable, except for the absence of coarse, frosted grains from sands in the overlying formation.[6]

Queen formation.—Within the Midland basin, the Queen formation includes the section from the top Grayburg dolomite stringer to the base of the main Whitehorse salt. The basal beds, characterized by the lowest zone of frosted quartz grains, are overlain in the structurally low areas by a prominent salt lens. Above this salt the Queen formation is largely made up of fine-grained orange-red sandstones and interbedded anhydrites. Salt is also present in many wells. Many of the sands contain coarse, milky white, frosted quartz grains. Due to the more rapid subsidence in the median areas during deposition, the Queen sand normally thickens toward the center of the basin and includes 1,100 feet of beds in one well several miles west of the line of the section. The appreciably greater thickness in Big Lake's University No. 1-C and the California's University No. 5 appears to be the result either of filling a local lagoonal area or of a local accumulation of dune sands. The sands in these and surrounding wells are very poorly cemented and flow freely into the open hole. Where the sandy phase is typically developed, the Queen sand resembles the Rush Springs sand of Oklahoma.

Seven Rivers formation.—In the Midland basin, the Seven Rivers

[6] In the Grayburg formation of the eastern Midland basin, the writers of this paper include what they believe are the stratigraphic and time equivalents of the type Grayburg of Eddy County, New Mexico. Locally their correlations do not agree with those of Dickey who, in their opinion, jumps upward in the section in passing from the Central Basin platform to the Midland basin and includes 150–200 feet of the overlying Queen formation in the top of the Grayburg.

A few coarse frosted quartz grains are reported from the type Grayburg sands but very few, if any, are present in that formation in the Midland basin area. Their abundance in the Queen sands and their absence in the underlying Grayburg of the eastern area furnish a means of separating the two formations lithologically.—Authors' note.

formation includes the section from the Yates sand to the base of the main Whitehorse salt section, an interval in the lowest wells shown of almost 800 feet. About two-thirds of this section consists of salt; the remainder is made up of anhydrite with minor amounts of sand and dolomite. The orange-red sands are fine and contain few coarse frosted grains. Near the margins of the basin the salt and much of the anhydrite grades into fine sand which characterizes the outcrop. As far as can be observed, the upper and lower contacts of the Seven Rivers are conformable. The Seven Rivers is similar to and probably in part equivalent to the Cloud Chief formation of Oklahoma.

Yates sand.—The typical Yates sandstone consists of uniform, fine-grained, orange-red sand containing an abundance of large, frosted quartz grains. In the structurally high areas, the red color is commonly lost due probably to the reducing activity of organic substances or petroleum emanations. Under such conditions, pyrite may be present as a cementing material. The average thickness is about 100 feet but varies on the section from 80 to 125 feet. Shale, anhydrite, and salt stringers occur, but the dominant lithology is the sandstone. The Yates sand is not definitely recognized on the eastern outcrops; if present, it would occur just below the contact of the overlapping Triassic. The Yates sand is probably younger than any of the Permian sediments of Oklahoma.

Tansill formation.—At the type locality, the Tansill as defined by DeFord, Riggs, and Wills in a forthcoming paper includes the upper Capitan dolomites above the Yates sand. Eastward these dolomites grade into anhydrite. In the Midland basin, the Tansill zone, which in few places is more than 100 feet thick, is made up of anhydrite with minor beds of salt, sand, and red shale. Marginward the salts disappear and the anhydrite is replaced by clastics. The Tansill anhydrites rest conformably on the Yates sand but are separated by a considerable time break from the overlying Upper Castile salt. The red shale commonly present at the top of the Tansill may represent weathering products developed during the deposition of the Lower Castile evaporites in the Delaware basin. The Tansill beds are more resistant electrically than the overlying and underlying beds and, as a result, they stand out prominently on electrical logs.

UPPER PERMIAN GROUP

Upper Castile salt.—Conformably above the Tansill anhydrites but separated from them, in the Midland basin, by a time break during which more than 1,000 feet of Lower Castile evaporites were deposited in the Delaware basin, is a thick series of saline deposits. These Upper Castile salts form the main salt series of the southern

basin. Salt predominates throughout the section with only a few interbedded, thin anhydrite, sand, and shale members. Sedimentation of this entire series was so uniform that one thin dolomitic anhydrite, the Cowden anhydrite member, described by Giesey and Fulk in a forthcoming paper, can be recognized throughout the salt basin.

The greatest thickness of salt along the line of section is only a little more than 500 feet. The thickest section present in the basin is more than 1,200 feet. Potash salts are present in some parts of the section. Polyhalite, the most common of the potash minerals, is widely distributed, occurring in a few wells below the Cowden anhydrite and has even been reported from the salts of the upper Whitehorse.

Near the eastern and southern margins of the basin, the salts grade into anhydrite and sand. Post-Permian erosion removed much of this nearshore sand and in some areas exposed the salt to solution. An effort was made to avoid the solution areas in selecting wells for the section but the effects can be seen in the abrupt thinning of the salt in the Superior's Logan No. 1. Triassic and Cretaceous beds completely overlapped the truncated edges and the Upper Castile redbeds are nowhere exposed in outcrops.

Rustler formation.—The thin series of anhydrites and sandy anhydrites above the Castile in the Midland basin constitute the eastern extension of the Rustler formation. In the western areas where the Rustler attains a thickness of more than 500 feet, it is separated from the underlying Castile by a pronounced angular unconformity. Eastward the unconformity decreases and, in the Midland basin, the two series are conformable although separated by a time break. On its eastern edge, the Rustler anhydrite grades within a short distance into redbeds but in most areas the beds are truncated where some anhydrite is still present. The Rustler represents the last period of chemical sedimentation in the Midland basin.

Dewey Lake formation.—Conformably above the Rustler anhydrites are fine to very fine orange-red sandstones and silts, similar in appearance to the clastics of the Whitehorse group. The silts and sands are well lithified and many have an anhydrite cement. A zone of coarse, frosted quartz grains is almost everywhere present in the lower 10 feet. These beds are classed as Permian because they rest conformably on the Rustler, commonly have an anhydrite cement, are well indurated, are similar in appearance and mineral content to the underlying Permian sands, and are separated from the overlying beds by an unconformity that is commonly marked by a zone of bleaching.

In the older literature, these uppermost Permian sands were called

Quartermaster; later they were classed as Pierce Canyon[7] when that formation was still regarded as Permian, but when it was re-defined to exclude all Permian beds a new name became necessary.

Since no complete section of these beds is found in the outcrops, it was decided to name them from a subsurface section. For this purpose, the section in the Penn's Habenstreit No. 1 in Glasscock County was selected. This well is located near the center of Sec. 47, Block 36, T. 3 S., Texas and Pacific Railroad Survey. The elevation of the well is 2,723 feet. It was a cable-tool well, completely dry, and abandoned in 1932 at a depth of 3,810 feet. A description of the cuttings from the Dewey Lake part of the Habenstreit well is as follows.

Depth in Feet	*Lithology*
1,135–1,155	Red silt (Tecovas, Triassic)
–1,172	Very fine red sandstone and silt, 90 per cent; micaceous gray shale, 10 per cent (Dewey Lake, Permian)
–1,222	Fine red sandstone with scattered flakes of dark mica and gypsum
–1,236	Fine red sandstone, 60 per cent; red silt, 40 per cent
–1,254	Fine to very fine red sandstone
–1,260	Fine red sandstone with some gypsum cement, 90 per cent; red shale, 10 per cent; trace gypsum
–1,268	Very fine red sandstone with gray mottles
–1,272	Red silt
–1,289	Red silt, 40 per cent; fine red sandstone, 60 per cent; some gypsum cement
–1,294	Fine red, micaceous sandstone
–1,369	Very fine red sandstone and silt
–1,379	Fine, red, micaceous sandstone
–1,407	Fine red sandstone with coarse, white and translucent, frosted quartz grains (Dewey Lake)
–1,416	Anhydrite (Rustler)

The Habenstreit well is shown on the cross section accompanying this paper and on that the relationships of the Dewey Lake redbeds to the remainder of the section can be seen. Dewey Lake, from which the formation is named, is an alkali lake in northern Glasscock County, Texas. It is the feature from which the Dewey Lake Quadrangle is also named.

TRIASSIC SYSTEM

DOCUM GROUP

The upper Triassic sediments of West Texas are included in the Dockum group. These redbeds are terrestrial deposits and consist mainly of clastics which range in coarseness from colloidal clays to boulders a foot or more in diameter. The group is here divided into three formations.

Tecovas formation.—The first Triassic sediments to accumulate were composed largely of reworked upper Permian sands and closely

[7] John Emery Adams, "Upper Permian Stratigraphy of West Texas Permian Basin," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19 (1935), pp. 1010–22.

resemble the underlying undisturbed Permian. However, a rich crop of new heavy minerals was introduced, the color was changed slightly, the percentage of biotite increased, and the reworked material has never attained the induration of the older beds. These basal silts have previously been classed with the underlying Dewey Lake redbeds as either Permian or Triassic. The thickness of the Tecovas shales in wells on the cross section varies from 30 to 200 feet. The irregularities in thickness are probably due largely to the irregular surface on which the formation was deposited and to gradation of the upper beds into the overlying Santa Rosa sands. Since no fossils have been found in these beds, it is not certain that they are all upper Triassic but they should be so classed until definite evidence of a different age is developed. The Tecovas beds are irregularly distributed along the margins of the basin and crop out both in Texas and New Mexico.

Santa Rosa and Chinle formations.—No attempt has been made to divide the upper members of the Dockum group. The Santa Rosa consists of a conglomeratic or coarse sand zone which can be easily separated from the fine silts and sands of the underlying Tecovas. On the east side of the basin, the Santa Rosa overlaps all the older beds down to and possibly including the Yates. Above the Santa Rosa and grading downward into it are the Chinle shales.

CRETACEOUS SYSTEM

Cretaceous beds, where present on the section, consist of a basement sand, probably of Paluxy age, overlain by Edwards-Comanche Peak limestones. Within this area the Cretaceous rests unconformably on beds ranging from middle Permian to uppermost Triassic.

SUMMARY

This paper is one of a series, by different authors, planned to establish a uniform series of formation names for the southern Permian basin. In introducing new and extending old names, as has been done, it is not the purpose to crowd out local names, many of which designate beds of great economic importance. Rather it is hoped that this paper will furnish a frame to which the local names can be tied.

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GEOLOGY OF NORTH-CENTRAL TEXAS[1]

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ABSTRACT

Because of the possible economic importance of the arched Ellenburger group, the identification of its subdivisions by insoluble residues and general character of well cuttings has been attempted with encouraging results.

To facilitate correlation of the Pennsylvanian and lower Permian strata, classification by "series" is proposed, based on unconformities and faunal changes of wide regional importance. Rearrangement of certain formations and groups is also advocated. Former stratigraphic names are retained where possible even though redefined or changed in rank.

Cross sections and maps reveal the Concho arch as an imposing northwest trending structural feature, denuded in the Llano uplift area. Uplift and erosion of Ordovician beds along this axis evidently began during pre-Mississippian time. Beds from Barnett to Strawn in age show marked thinning and considerable truncation as this regional feature is approached.

Attention is also given to the evidence of intermittent growth of the Ouachita-Marathon Mountains, the Electra and Muenster arches. The Bend flexure and other large structural features of this region are described.

Regional conditions affecting oil and gas migration and accumulation are discussed. These include the progressive development of structural trends and local folds, overlap of structurally high reservoirs by apparent source beds, differential pressures resulting from wedge-shaped overburden, distribution of sedimentary material, and the development of local sandstone or limestone reservoirs and stratigraphic traps. A "compaction-hydraulic theory" of oil migration is favored as the main cause of movement of oil into and laterally within the reservoir toward areas of less overburden and pressure.

INTRODUCTION

Geological investigation and drilling activities during the past quarter century in north-central Texas have yielded a vast number of geological data and approximately 1 billion barrels of oil. Discoveries during the past 2 years of additional reserves estimated in excess of 250 million barrels give ample evidence that, although the district is nearly 20 years past its "boom" stage, there remains economic as well as scientific incentive for continued effort, particularly under improved methods of oil exploration, development, and production. This region, commonly referred to in oil reports as West-Central and North Texas, includes about the same area as Pennsylvania, and has now surpassed that state in total recovery of oil.

The strata of this area have been described and classified in previous publications as summarized by Sellards.[3] Extensive studies of outcropping beds have been supplemented by data from drilling, thereby revealing the stratigraphy in three dimensions over much

[1] Read before the Association at El Paso, September 29, 1938. Manuscript received, October 23, 1939.

[2] President, Anzac Oil Corporation.

[3] E. H. Sellards, "The Geology of Texas," Vol. 1, *Univ. of Texas Bull. 3232* (1932).

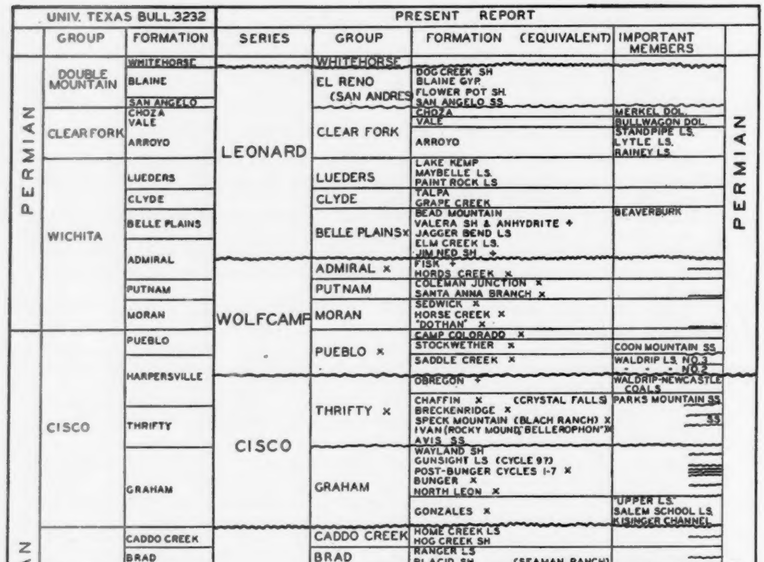


FIG. 1.—Stratigraphic classification table of Paleozoic strata of north-central Texas.

of the area. Intersecting cross sections are included herein to illustrate graphically the character, thickness, and lateral changes of the sediments. Many lateral variations occur in these shallow-water deposits, yet certain general features are recognized over large areas.

Continued study of these strata has disclosed the need of considerable revision of stratigraphic classification if the major divisions are to be based not on local lithologic character but on faunal changes and diastrophic movements of sufficient significance to be used in making correlations with other regions. Also if more conventional usage of the terms "member" and "formation" is to be followed, a general revision of these lesser units is required. Figure 1 shows changes of classification suggested to attain these objectives.

Pre-Pennsylvanian Stratigraphy

Pre-Pennsylvanian beds have yielded less than one per cent of the oil produced to date in north-central Texas. It is still problematical whether, as in Oklahoma and Kansas, large oil reserves will be found in older beds after extensive development of Pennsylvanian reservoirs has taken place. With this possibility in mind, the pre-Pennsylvanian beds have been given special study. There is but little difficulty in most of this region in identifying from well cuttings the Mississippian and Cambrian shales and sandstones, but the intervening limestone and dolomite, Lower Mississippian to Upper Cambrian in age, are not readily separable into formations.

The base of the Barnett formation is used as a stratigraphic reference and structural datum because in a large part of this region brown or black shales, up to 150 feet thick, below dark limestone members and above a thick zone of white or light-colored limestone and dolomite make its identification reasonably certain. The exact position of the base of the Chappel limestone (Lower Mississippian) remains in doubt in many wells, especially where drill cuttings are not available. The formation attains a thickness of about 300 feet in Throckmorton County. The term Chappel limestone formation should perhaps be restricted to an upper thin fossiliferous coarse crystalline member correlated with the Welden limestone of Oklahoma. The underlying denser, siliceous limestone and cherty Mississippian beds may be equivalent to the Sycamore limestone of southern Oklahoma, to which it shows much resemblance both lithologically and in eastward loss of section. Cooper has described these beds of Meramec, Osage, and upper Kinderhook (?) age in Oklahoma.[4]

[4] C. L. Cooper, "The Sycamore Limestone," *Oklahoma Geol. Survey Circ. 9* (1926), and "Conodonts from a Bushberg Hannibal Horizon in Oklahoma," *Jour. Paleon.*, Vol. 13 (1939), pp. 379–422.

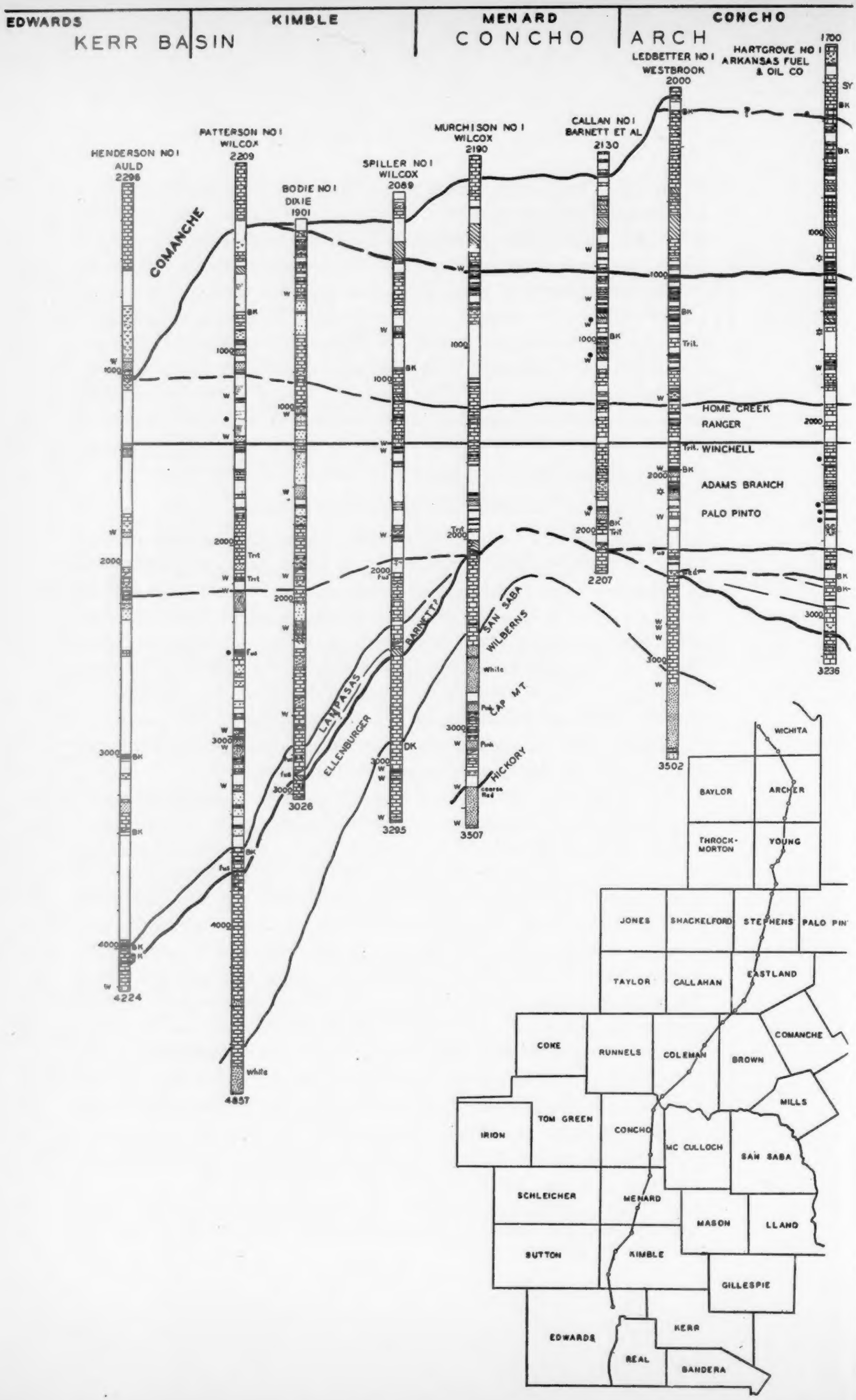
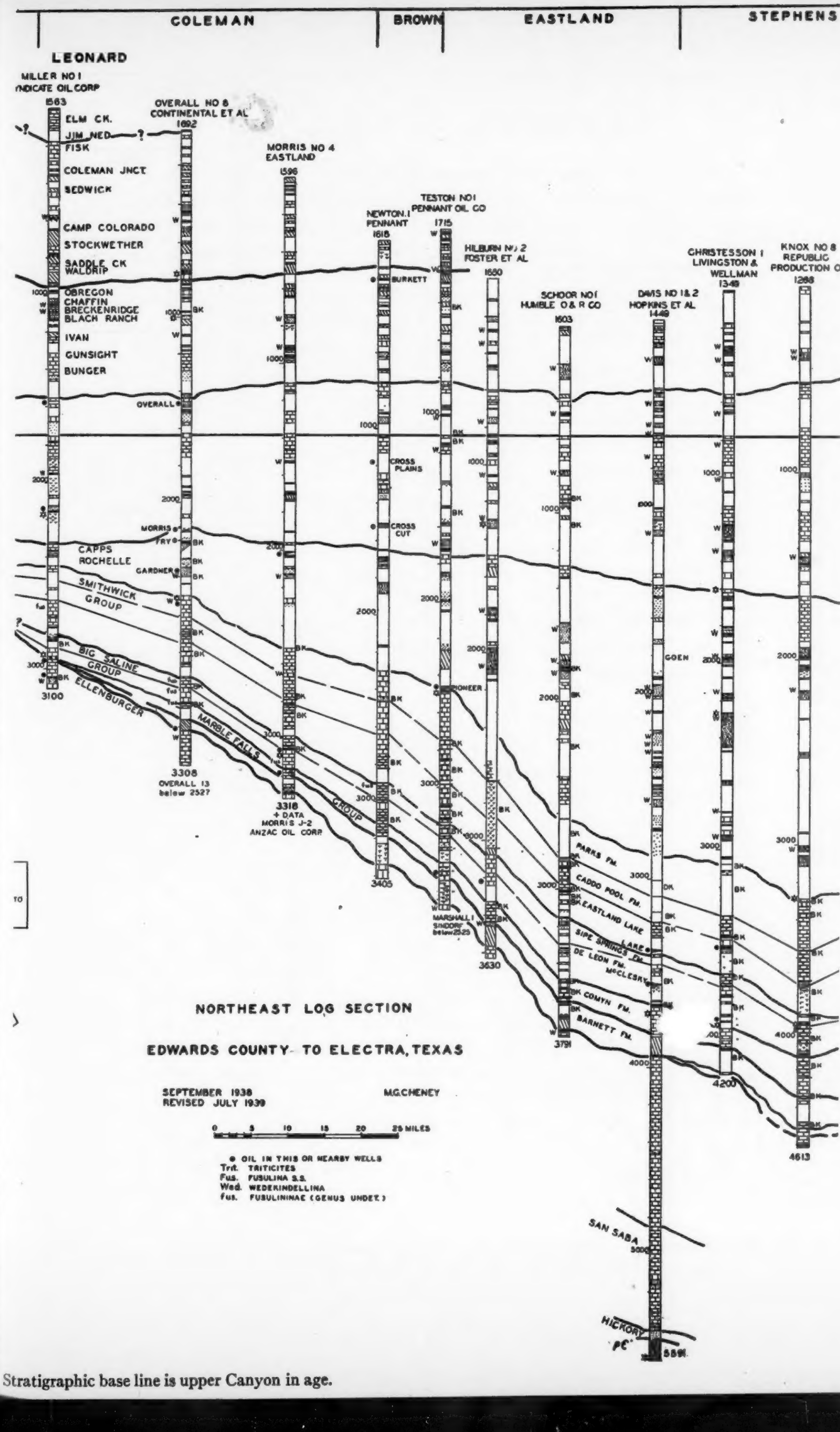


FIG. 2.—Northeast log section, Edwards County to Electra, Texas.



Stratigraphic base line is upper Canyon in age.

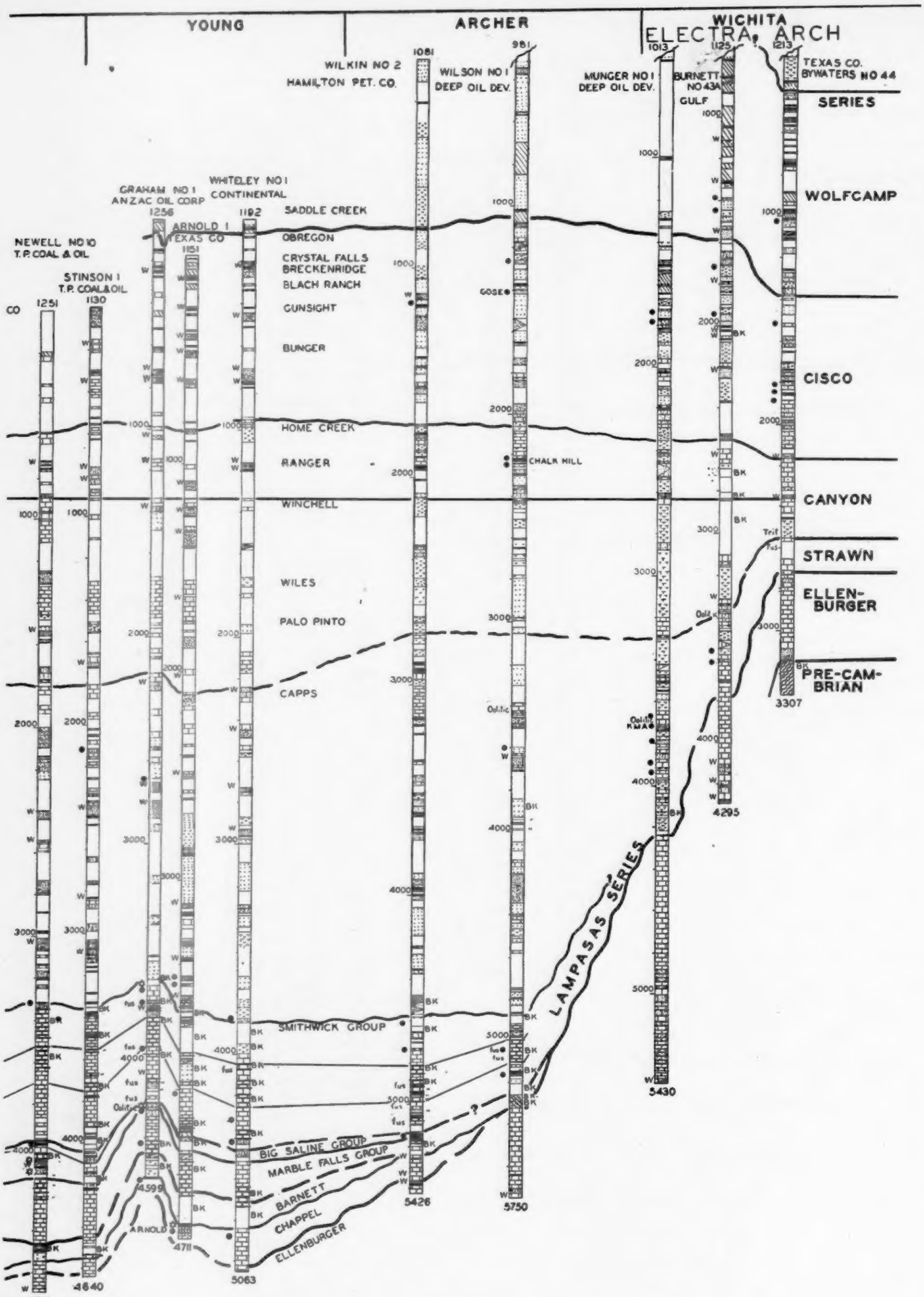


FIG. 2 (*continued*).—Northeast log section, Edwards County to Electra, Texas. Stratigraphic base line is upper Canyon in age.

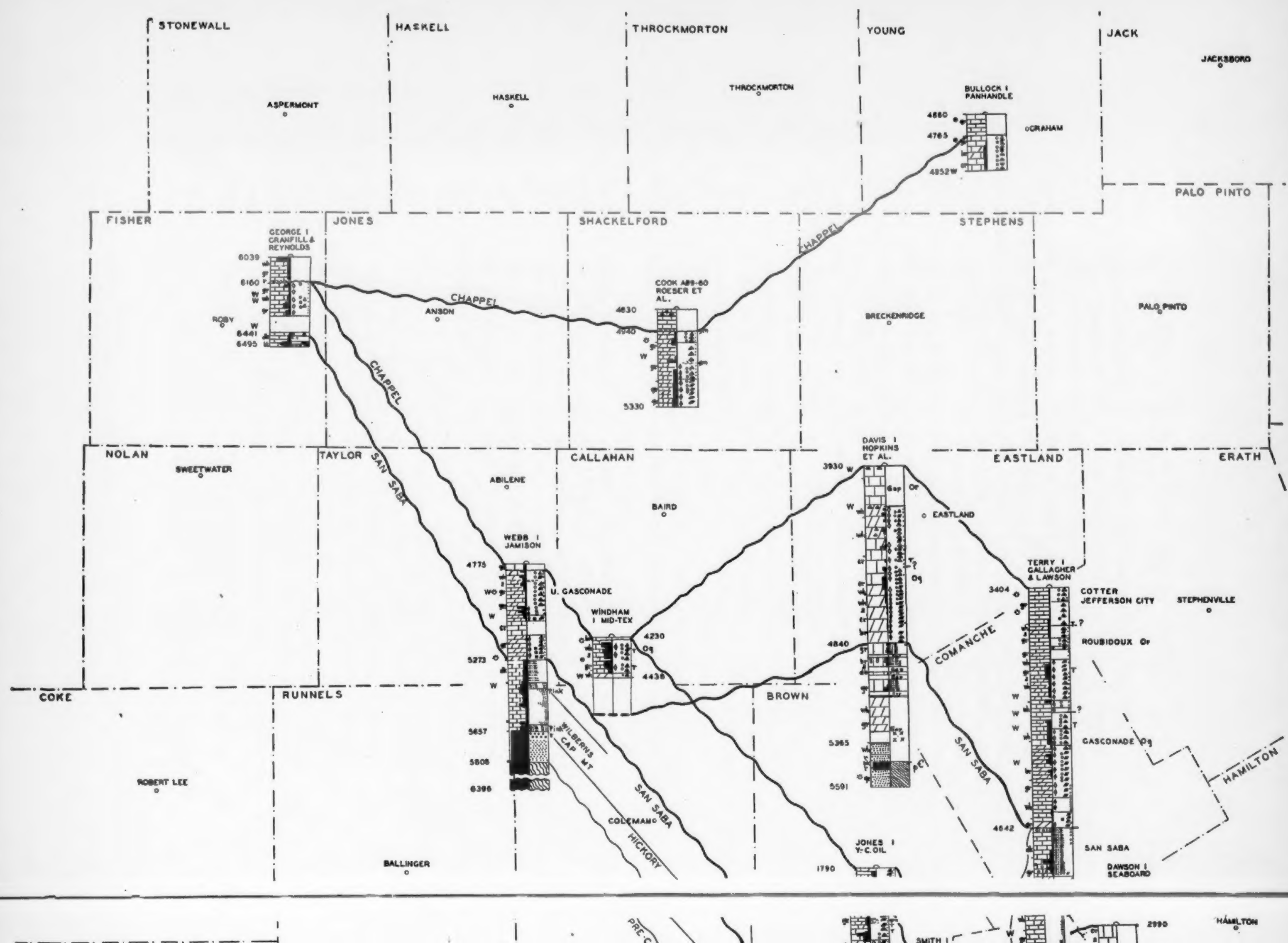
Unconformities above and below the Mississippian beds converge toward areas of greatest uplift, that is, the Muenster and Electra arches of the Red River uplift region and the Concho arch (Llano uplift and northwest trend) where locally in each case these Mississippian and early Pennsylvanian beds are absent (Fig. 2). In spite of proximity, the Upper Ordovician, Silurian, and Devonian deposits of southern Oklahoma and trans-Pecos Texas may be expected only far down on the flanks of these arches.

Deep tests in Hamilton and Taylor counties have revealed westward regional reduction in thickness of Ellenburger beds from 2,400 feet plus to about 400 feet beneath overlapping Mississippian deposits. This is shown graphically in Figure 3 in which HCl—insoluble residues of pre-Barnett formations are used as a basis of correlation. Type residue material was obtained from outcrop samples of the various divisions of the Ellenburger beds as determined by Dake and Bridge[5] in the Llano uplift area. While more exhaustive study is needed, it is apparent that the character of residue and sequence of insoluble percentages give a two-fold basis for subdividing the Ellenburger into formational units. Additional work is contemplated to make more certain the correlation between subsurface and outcrop areas and to distinguish, if possible, more index material of limited vertical range.

Very distinctive insoluble residues are commonly obtained from the beds above and below the Ellenburger. A variable mixture of spicular, microfossiliferous, porous and vitreous cherts distinguishes the overlying Chappel limestone. A peculiar fine siliceous network of clear rod-like crystals or spicules and small glauconite grains characterizes the San Saba[6] limestone formation (Signal Mountain-Fort Sill equivalents) below the Ellenburger. According to the tentative correlations as shown in Figure 3, the Cotter-Jefferson City equivalents (upper Ellenburger) contain relatively small amounts of various types of chert (without microfossils), green shales, oölites, and large, rounded, frosted sand grains. The upper Roubidoux equivalent is mainly composed of limestone or dolomitic limestone with similar residue material in very small amount, whereas the lower Roubidoux equivalent contains a relatively large insoluble content including some druse. Large, rounded, frosted sand grains form a larger proportion of the residue and are more uniformly present than in divisions above and

[5] C. L. Dake and Josiah Bridge, "Faunal Correlation of the Ellenburger Limestone of Texas," *Bull. Geol. Soc. America*, Vol. 43 (1932), pp. 725-48.

[6] Name proposed at field conference, July, 1938, by Josiah Bridge to be used in forthcoming publications, type locality being Camp San Saba district, southern McCulloch County, Texas.



STONEWALL
HASKELL
THROCKMORTON
YOUNG
JACK
JACKSBORO
ASPERMONT
HASKELL
THROCKMORTON
BULLOCK I PANHANDLE
4660
4765
4852W
GRAHAM
PALO PINTO
FISHER
JONES
SHACKELFORD
STEPHENS
GEORGE I CRANFILL & REYNOLDS
6039
6160
ROBY
6441
6495
CHAPPEL
ANSON
COOK A89-60 ROESER ET AL.
4830
4940
5330
BRECKENRIDGE
PALO PINTO
NOLAN
SWEETWATER
TAYLOR
SAN SABA
ABILENE
CALLAHAN
BAIRD
DAVIS I HOPKINS ET AL.
3930
EASTLAND
ERATH
WEBB I JAMISON
4775
U. GASCONADE
WINDHAM I MID-TEX
4230
4438
4840
COMANCHE
TERRY I GALLAGHER & LAWSON
3404
COTTER JEFFERSON CITY
STEPHENVILLE
ROUBIDOUX
5273
COKE
RUNNELS
BROWN
5657
5808
6396
WILBERNS
CAP MT
5365
5591
GASCONADE
HAMILTON
ROBERT LEE
COLEMAN
HICKORY
JONES I Y-C OIL
1790
4642
SAN SABA
DAWSON I SEABOARD
BALLINGER
2990
SMITH I
PRE-C

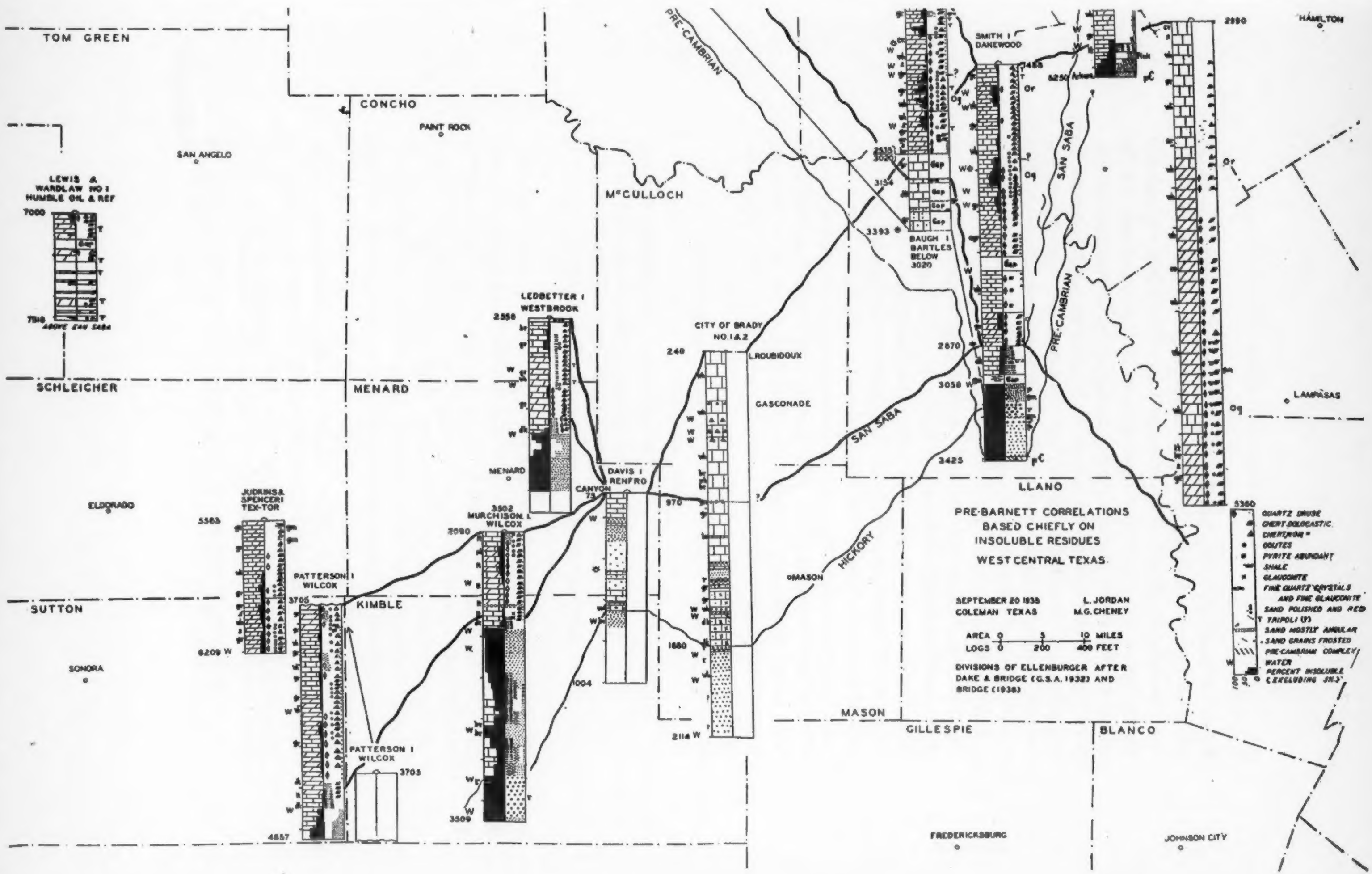


FIG. 3.—Pre-Barnett correlations based chiefly on character and percentages of insoluble residues (excepting shale). Extensive truncation of Ellenburger during pre-Barnett time is evident in Concho arch region.

below. According to the Cherokee-San Saba outcrop section, the upper Gasconade equivalent should include about 100 feet of cherty beds over a nearly like thickness of pure limestone of the middle Gasconade equivalent. However, according to present correlation of wells on the north, each of these subdivisions has two or three times this thickness. The upper Gasconade as thus correlated contains an exceptional development of insoluble oölites as well as some chert and druse. The middle Gasconade equivalent consists of dolomite and limestone with very little residue, the chert present being almost exclusively dolocastic and oölites rare. The lower Gasconade equivalent evidently becomes very thin or absent locally toward the Concho axis, its residue consisting mainly of druse, dolocastic chert, and some sand grains near the base. A westward or northwest loss or thinning of lower Gasconade, Eminence, and Potosi equivalents as reported by Dake and Bridge is borne out by wells included in Figure 2. Green shale and fine, white, powdery material which may be tripoli are present in noticeable amounts at varying positions in the section, but probably more abundantly in the lower Roubidoux equivalent and the upper Gasconade equivalent than elsewhere in the Ellenburger section.

PENNSYLVANIAN AND PERMIAN STRATIGRAPHY

CLASSIFICATION

Much has been written during the past 50 years regarding the Pennsylvanian and Permian beds of north-central Texas.[7] In the present paper discussion will be limited to questions of classification and subdivision, and certain important faunal and stratigraphic data accumulated during recent years.

The accompanying cross sections (Figs. 2 and 4), show the character of the sedimentary rocks of this region as well as their general classification under proposed revisions. In this paper the writer has chosen to follow the practice of several State geological surveys and many American geological textbooks, of treating the Mississippian, Pennsylvanian, and Permian deposits as three systems rather than as composing two systems (Carboniferous and Permian), as do most European geologists, or only one system, as has been the practice of the United States Geological Survey. Systemic classifications established by early geological investigations in Europe necessarily depended on more or less local and incomplete geologic sections. These early concepts may well serve as anchorage but might prove stifling

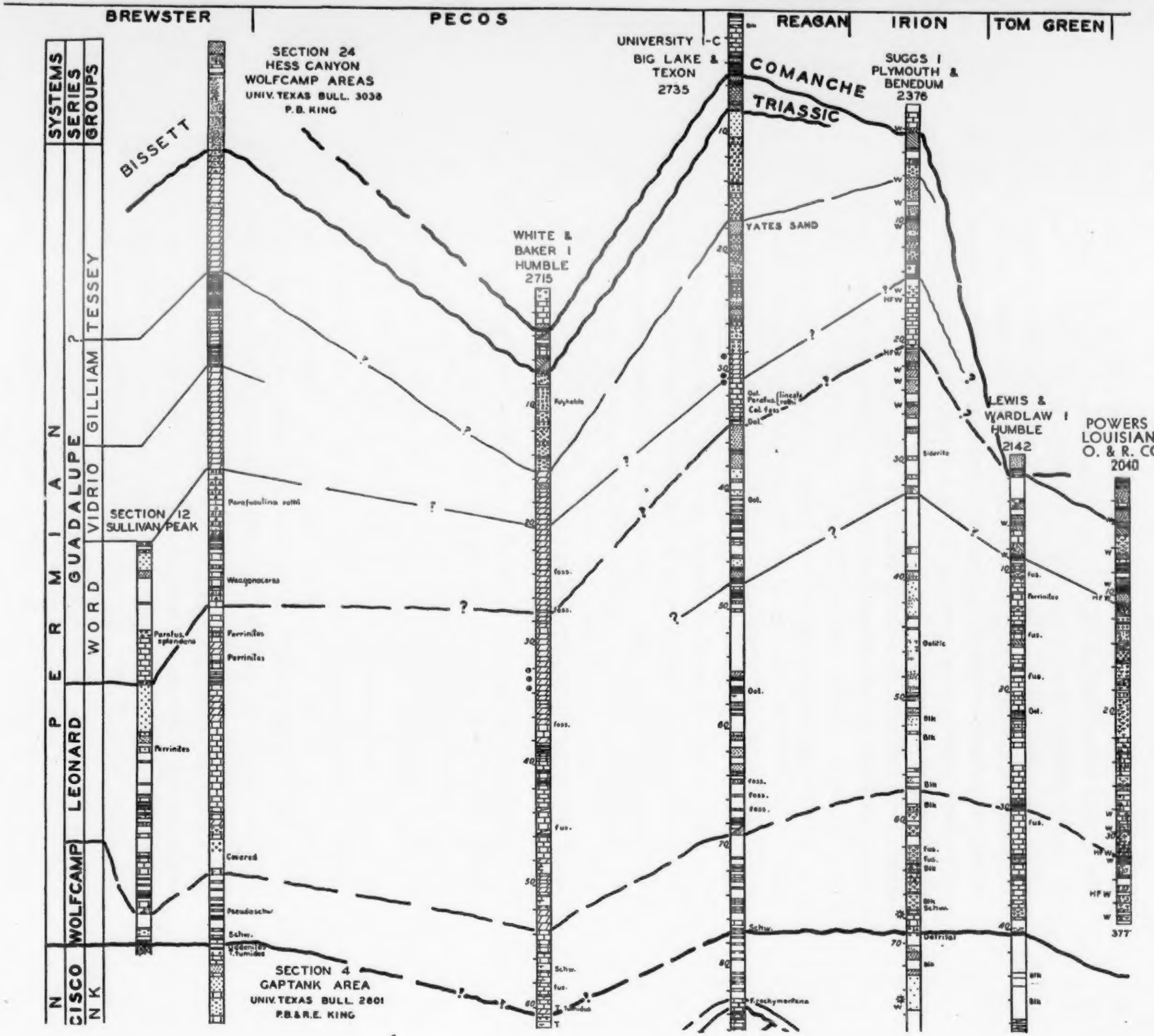
[7] E. H. Sellards, "The Geology of Texas," *Univ. Texas Bull. 3232* (1932). Bibliography and subject index, pp. 819–1007.

to the science if adhered to with excessive rigidity. Many years ago the United States Geological Survey decided that the Mississippian, Pennsylvanian, and Permian should be classified as of equal rank. As closer study and greater differentiation of these sediments proceed, it becomes increasingly difficult to treat so great and varied a sequence of beds as a single system, or such an extended time interval and series of geologic events as one period. In fact Harlton's[8] proposal that the Pennsylvanian be divided into two systems, the Bendian and Pennsylvanian, has considerable justification in view of the apparent major geologic cycles represented by each of these divisions. The Stanley, Jackfork, and Morrow may well be interpreted as a flysch, molasse, and marine sequence of deposition in the Ouachita basin of southeast Oklahoma, thereby recording the development and dying out of very extensive diastrophic movements in both Llanoria and Mid-Continent regions. The subsequent Pennsylvanian deposits of the area record a somewhat similar sequence associated with progressive Ouachita, Arbuckle, and Wichita Mountain orogenies. These two major divisions are separated from each other and from overlying and underlying sediments by very great and widespread unconformities. Each may be divided into major subdivisions separated by lesser but nevertheless important unconformities, disconformities, and faunal changes.

During the Pennsylvanian period, large areas became geosynclines filled with shallow-water deposits several miles thick. As recorded in the Marathon area, these geosynclines experienced diastrophism of the most extreme character, followed by regional uplift and truncation measurable in thousands of feet of vertical changes, all prior to inundation beneath early Permian (Wolfcamp) seas. Extensive uplift and erosion prior to deposition of Pennsylvanian marine sediments resulted in a hiatus of great magnitude between Pennsylvanian and Mississippian deposits over large areas. It is believed assuredly that such a vast array of geologic events and depositional, structural, and erosional history must give systemic rank to the deposits of Pennsylvanian age. Over very large areas the Mississippian deposits are also bounded by profound unconformities, hence the Mississippian deposits (15,000 feet thick in some areas and necessarily representing a very great extent of time) also appear properly classified as a system.[9]

[8] Bruce H. Harlton, "Stratigraphy of the Bendian of the Oklahoma Salient of the Ouachita Mountains," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22 (1938), pp. 852–914.

[9] M. Grace Wilmarth, "The Geologic Time Classification of the United States Geological Survey," *U. S. Geol. Survey Bull. 769* (1925), pp. 5–6.


BREWSTER
PECOS
REAGAN
IRION
TOM GREEN
SYSTEMS
SERIES
GROUPS
PERMIAN
GUADALUPE
LEONARD
WOLFCAMP
CISCO
TESSEY
GILLIAM
VIDRIO
WORD
BISSETT
SECTION 24
HESS CANYON
WOLFCAMP AREAS
UNIV. TEXAS BULL. 3038
P.B. KING
SECTION 12
SULLIVAN PEAK
SECTION 4
GAPTANK AREA
UNIV. TEXAS BULL. 2801
P.B.&R.E. KING
WHITE &
BAKER I
HUMBLE
2715
UNIVERSITY I-C
BIG LAKE &
TEXON
2735
COMANCHE
TRIASSIC
YATES SAND
SUGGS I
PLYMOUTH &
BENEDUM
2376
LEWIS &
WARDLAW I
HUMBLE
2142
POWERS I
LOUISIANA
O. & R. CO.
2040

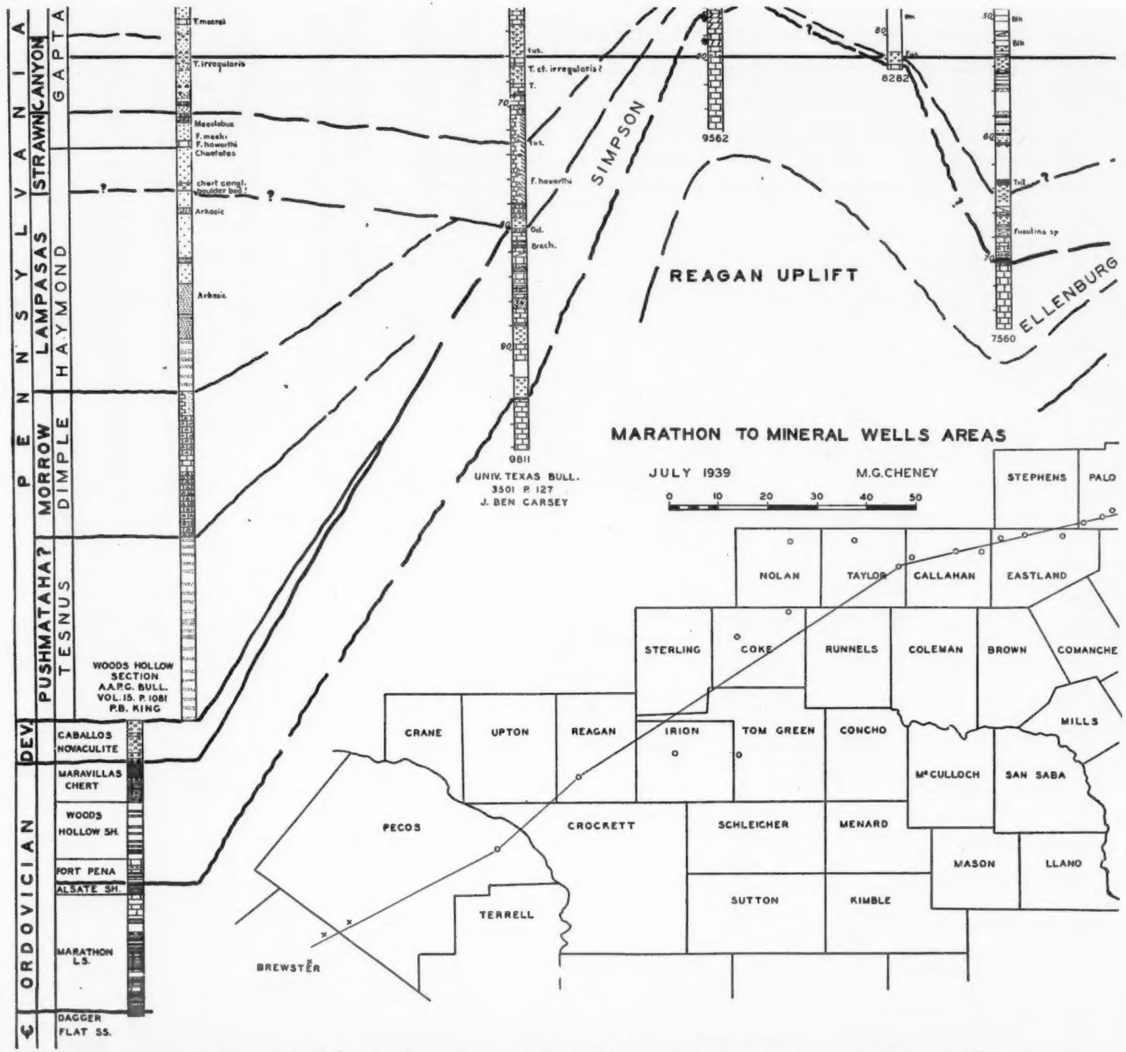
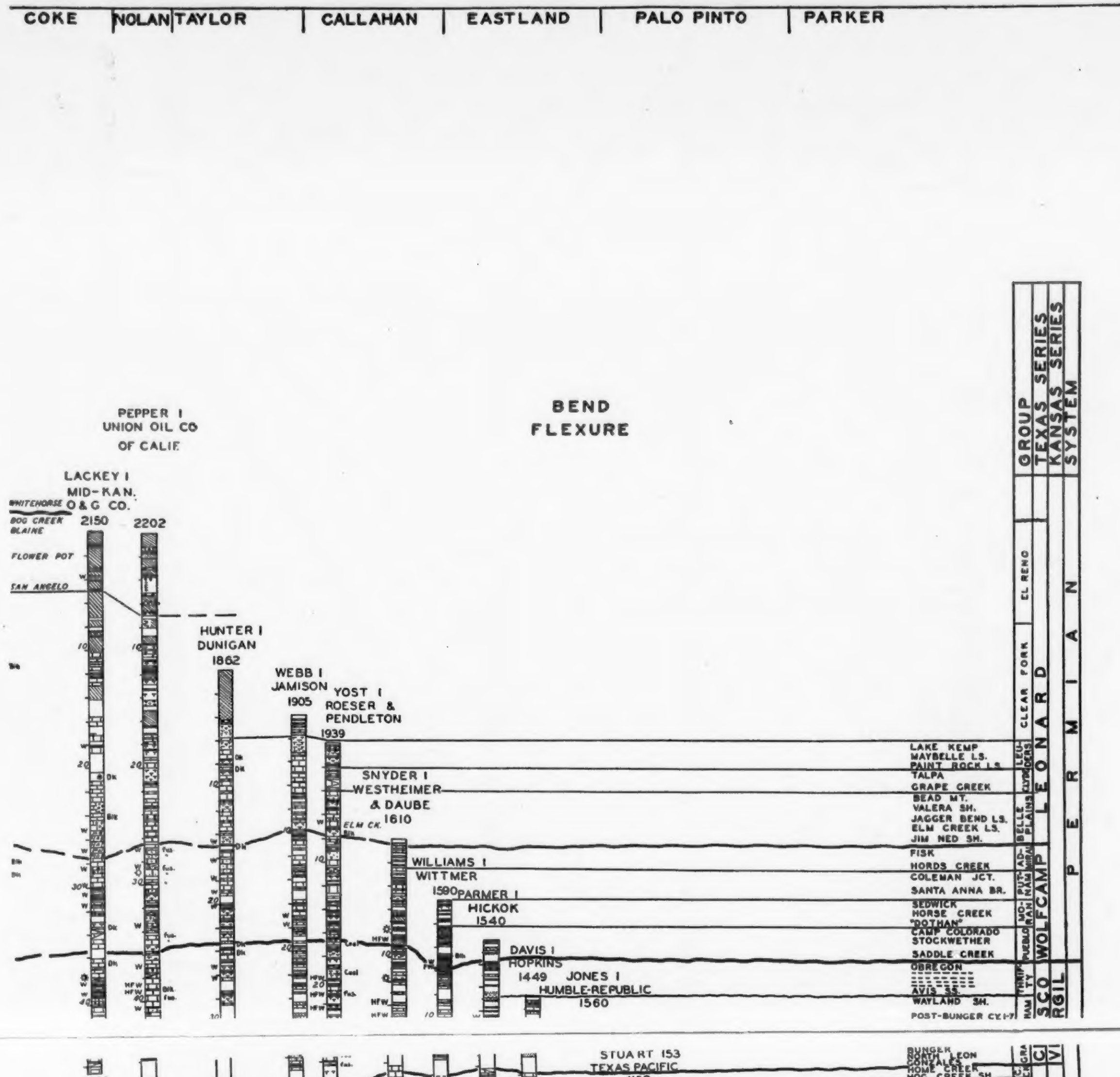


FIG. 4.—West-east log section from Marathon area to Mineral Wells area. Stratigraphic base line is upper Canyon in age.


COKE
NOLAN
TAYLOR
CALLAHAN
EASTLAND
PALO PINTO
PARKER
BEND FLEXURE
PEPPER I UNION OIL CO OF CALIF. 2202
LACKEY I MID-KAN. O & G CO. 2150
WHITEHORSE
DOG CREEK
BLAINE
FLOWER POT
SAN ANGELO
HUNTER I DUNIGAN 1862
WEBB I JAMISON 1905
YOST I ROESER & PENDLETON 1939
SNYDER I WESTHEIMER & DAUBE 1610
ELM CK.
WILLIAMS I WITTMER 1590
PARMER I HICKOK 1540
DAVIS I HOPKINS 1449
JONES I HUMBLE-REPUBLIC 1560
STUART 153 TEXAS PACIFIC 1152
4255
LAKE KEMP
MAYBELLE LS.
PAINT ROCK LS.
TALPA
GRAPE CREEK
BEAD MT.
VALERA SH.
JAGGER BEND LS.
ELM CREEK LS.
JIM NED SH.
FISK
HORDS CREEK
COLEMAN JCT.
SANTA ANNA BR.
SEDWICK
HORSE CREEK
"DOTHAN"
CAMP COLORADO
STOCKWETHER
SADDLE CREEK
OBREGON
AVIS SS.
WAYLAND SH.
POST-BUNGER CY.
GROUP
TEXAS SERIES
KANSAS SERIES
SYSTEM
EL RENO
CLEAR FORK
LEONARD
WOLFCAMP
PERMIAN

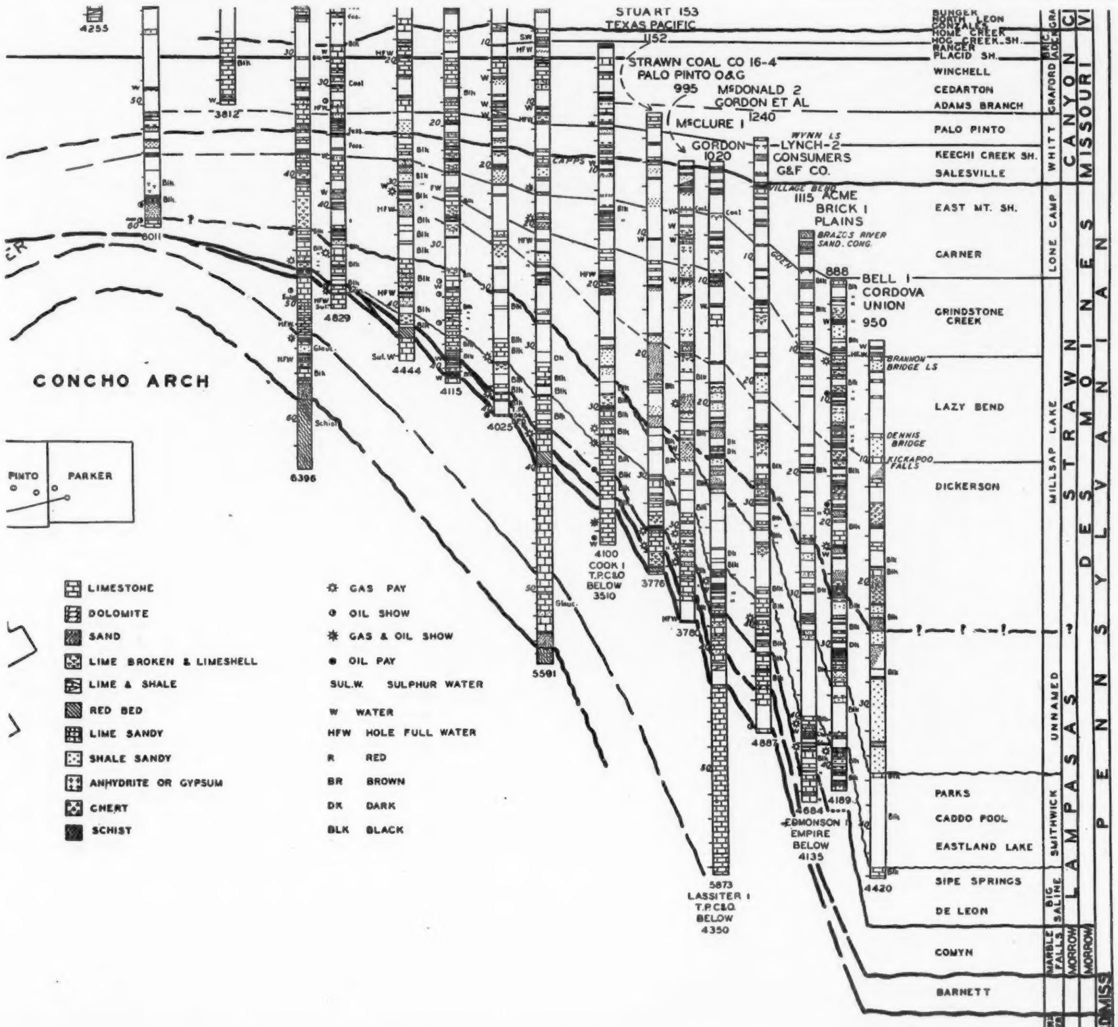


FIG. 4 (*continued*).—West-east log section from Marathon area to Mineral Wells area. Stratigraphic base line is upper Canyon in age.

Likewise, it seems appropriate to consider setting precedent aside in regard to major subdivisions of the Pennsylvanian and Permian systems in north-central and West Texas. Early classifications by lithologic groups have led to much confusion because of lateral changes in lithology. To illustrate this point, on a group basis it appeared reasonable one or two decades ago to correlate the Capps limestone, Ricker beds, and Rochelle conglomerate of the Colorado River district as being at least approximately equivalent to the Palo Pinto formation of the Brazos River district. By stressing faunal studies and series boundaries, these beds are now correlated with beds from 600 to 1,000 feet below the Palo Pinto formation in the Brazos River outcrop area. Much more significant division may now be made by establishing several *series* identified by important faunal assemblages separated by widespread diastrophic breaks. It is recognized that the term "series" may be used either as a provincial or as a worldwide major division of a system according to the generally recognized code of nomenclature,[10] the provincial applications being necessitated mainly by lack of contemporaneity of diastrophic movements in different areas with resultant differences of position of unconformities or disconformities, and of character of deposits and fauna.

In this report the type Marble Falls beds are considered as a group, being a part of the Morrow series. Classification of Smithwick as a group of the Lampasas series is suggested. The Strawn, Canyon, and Cisco, with moderate boundary revisions, are treated as of series rank. Retention of these Texas names for the present at least is preferred by most geologists working in this area, since this will cause less difficulty than attempting to introduce northern Mid-Continent names with divisions and correlations which may require subsequent revisions. This is done without disparagement of the importance and primacy of the work done chiefly by the Kansas and Nebraska geological surveys, by Moore, Condra, and associates, in differentiating into series the Pennsylvanian sediments of these states.

Because of proximity and subsurface connection, it seems logical to use the well established Glass Mountain subdivisions and terminology for related beds of north-central Texas, particularly the Wolfcamp and Leonard series with their distinctive faunas and boundary unconformities. The correlations made between these two areas in Figure 4 should be treated as preliminary and tentative.

[10] "Classification and Nomenclature of Rock Units," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23 (1939), p. 1074.

PENNSYLVANIAN SYSTEM

Subdivisions of the Pennsylvanian system, established several decades ago on the basis of lithology in a region more or less deficient in marine faunas, have not proved readily determinable in other areas.[11] The Mid-Continent region has been suggested as being much more suitable for the determination of a standard Pennsylvanian section of North America.[12] However, the proposed four-fold series classification[13] seems neither adequate nor entirely applicable. Harlton[14] has presented evidence in favor of placing the Stanley and Jackfork groups of the "Bendian system" of southern Oklahoma in a separate series called *Pushmataha* with maximum aggregate thickness of more than 9,000 feet beneath 2,000 feet of beds of the Morrow series. A post-Morrow and pre-Strawn series between the type Marble Falls and Strawn sediments also appears necessary to meet conditions observed in north-central Texas. The name *Lampasas* series is proposed for beds younger than Morrow but older than type Strawn of the Brazos River Valley section. The type Marble Falls section of Burnet County doubtless belongs to the Morrow series, but the "Marble Falls" beds observed in McCulloch and Kimble counties are for the most part believed to be post-Morrow. The type Strawn of the Brazos River Valley section is meant to include the unexposed shales, sandstones, and limestones that are faunally and structurally related to younger northwestward-dipping strata of Strawn age observed in outcrops.

The name Lampasas is taken from Lampasas County, Texas. This series forms an extensive wedge between eastward-dipping type Marble Falls and westward-dipping Strawn beds. The best outcrops of the Lampasas beds are to be found in western Lampasas and eastern San Saba counties near the village of Bend. Post-Smithwick sandstones and dark shales exposed in western Lampasas County may prove to be of Lampasas age. Drake[15] noted extensive southeast dips in the sandstone and shales in this area which suggests that these beds are more related to the Smithwick than to the Strawn.

[11] H. R. Wanless, "Pennsylvanian Correlations in the Eastern Interior and Appalachian Coal Fields," *Geol. Soc. America Spec. Paper 17* (1939).

[12] R. C. Moore, "Proposed New Type Section of the Pennsylvanian System," *Bull. Geol. Soc. America*, Vol. 43 (1932), p. 279.

[13] *Idem*, "Upper Carboniferous Rocks of Southeastern Kansas and Northeastern Oklahoma," *Eleventh Annual Field Conference, Kansas Geol. Soc.* (1937), p. 11.

[14] B. H. Harlton, *op. cit.*, p. 853.

[15] N. F. Drake, "Report on Colorado Coal Fields of Texas," *Univ. Texas Bull. 1755* (1892), reprint (1917), pp. 17–19.

In southeastern Oklahoma the regional unconformities at the top of the Morrow and at the base of the Savanna are considered as marking the lower and upper boundaries of the Lampasas series. The unconformity at the top of the Morrow is widely recognized in Oklahoma and Arkansas. The unconformity at the base of the Savanna group marks the initiation of the Boggy overlap[16] of central Oklahoma which appears comparable to the Strawn overlap of north-central Texas. The genus *Mesolobus*, so characteristic of the Strawn (Des Moines) series is thought to be absent in the Lampasas series. It was not reported in extensive faunal collections made by Wilson and Newell[17] from pre-Savanna beds in southeast Oklahoma. The Lampasas epoch marks the first appearance of the family Fusulinidae, possibly excepting the genus *Stafella*. Development of *Fusiella* and *Fusulinella* occurred during Big Saline[18] time and early types of *Wedekindellina* and *Fusulina* ss. during the Smithwick epoch. *Fusiella* is thought to be limited to the Big Saline and the other three genera to Lampasas and Strawn beds. Upper Pottsville and lower Allegany beds of the older classification are included in the Lampasas series. Some geologists advocate restricting this post-Morrow series to beds of Atoka (upper Pottsville) age. However, this would conflict with including Smithwick beds which are set apart from the Strawn series by the most pronounced unconformity noted between succeeding units of the entire Paleozoic system in north-central Texas. About 2,500 feet of Dornick Hills beds from the base of the Bostwick or somewhat lower up to or nearly to the Pumpkin Creek beds are thought to represent the Lampasas series in the Ardmore basin area.

MORROW AND LAMPASAS SERIES

It is recognized that the Marble Falls and Smithwick deposits as seen at the outcrop form a natural unit structurally, for many years referred to as the Bend "series" or Bend group. When studied regionally, including areas where covered by later sediments, these beds are logically divisible into three lesser groups. The term *group* has such broad meaning and wide application without regard to series boun-

[16] G. D. Morgan, "Boggy Unconformity and Overlap in Southern Oklahoma," *Oklahoma Bur. Geol. Circ. 2* (1924).
Robert H. Dott, "Pennsylvanian Paleogeography," *Oklahoma Geol. Survey Bull. 40*, Vol. 1 (1928), pp. 58–61.
R. C. Moore, "Late Paleozoic Crustal Movements of Europe and North America," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19 (1935), p. 1276, Fig. 9.

[17] C. W. Wilson and N. D. Newell, "Geology of the Muskogee-Porum District, Oklahoma," *Oklahoma Geol. Survey Bull. 57* (1937), p. 19.

[18] Lowest group of Lampasas series; see definition under heading "Morrow and Lampasas series."

daries that continued use, when needed, of the term *Bend group* does not appear inconsistent with usage of these lesser group names, the oldest of which is the assemblage of alternating gray and black limestone with varying siliceous and fossil content of the type section at Marble Falls with definite Morrow fauna. In much of north-central Texas these type Marble Falls beds are unconformably overlain by a group of shales, sandstone, and limestone, which is herein named the *Big Saline* group, the type locality being near the mouth of Big Saline Creek in eastern Kimble County from which *Fusiella primaeva* and *Fusulinella llanoesis*[19] were first described. The well known Smithwick shales, limestones, and sandstones form the third group. The Big Saline beds have been commonly included with the Marble Falls, but because of regional unconformity between them and notably different lithology and fauna, it appears that they should belong to different groups and probably to different series. It is recalled that the type Marble Falls beds are generally correlated with the Otterville and Wapanucka limestone and the upper part of the Morrow series of southern Oklahoma, also that fusulinids of the Big Saline beds make their first appearance in the Bostwick and lower Atoka beds of southern Oklahoma which are generally considered post-Morrow. The coarse sands and conglomerates present in the Big Saline, Bostwick, and Atoka beds show that their deposition accompanied or followed active orogeny. The Criner Hills area offers very definite evidence of this orogeny. As reported by Tomlinson[20] the coarse conglomerates of the Bostwick formation decrease in size and thickness away from this exposed unit of the Wichita Mountain system.

Westward loss of thickness of the type Marble Falls limestone may be nofed in outcrop areas, the thickness being 368 feet in the Marble Falls area and 40 feet in east-central McCulloch County. Well samples show an entire absence of these beds in western Coleman and Callahan counties (Figs. 2 and 4). Marked variation in thickness of type Marble Falls and Barnett beds within short distances demonstrates that local as well as regional folding and erosion occurred prior to deposition of the Big Saline group.

The Big Saline group is represented by some 50 feet of fusulinid-bearing limestones and shales in east-central McCulloch County 4 miles south-southwest of Rochelle. These beds become more shaly eastward and their identity at the outcrop less certain. As traced

[19] Norman L. Thomas, "New Early Fusulinids from Texas," *Univ. Texas Bull. 3101* (1931), pp. 27-33.

[20] C. W. Tomlinson, "The Pennsylvanian System in the Ardmore Basin," *Oklahoma Geol. Survey Bull. 46* (1929), p. 30.

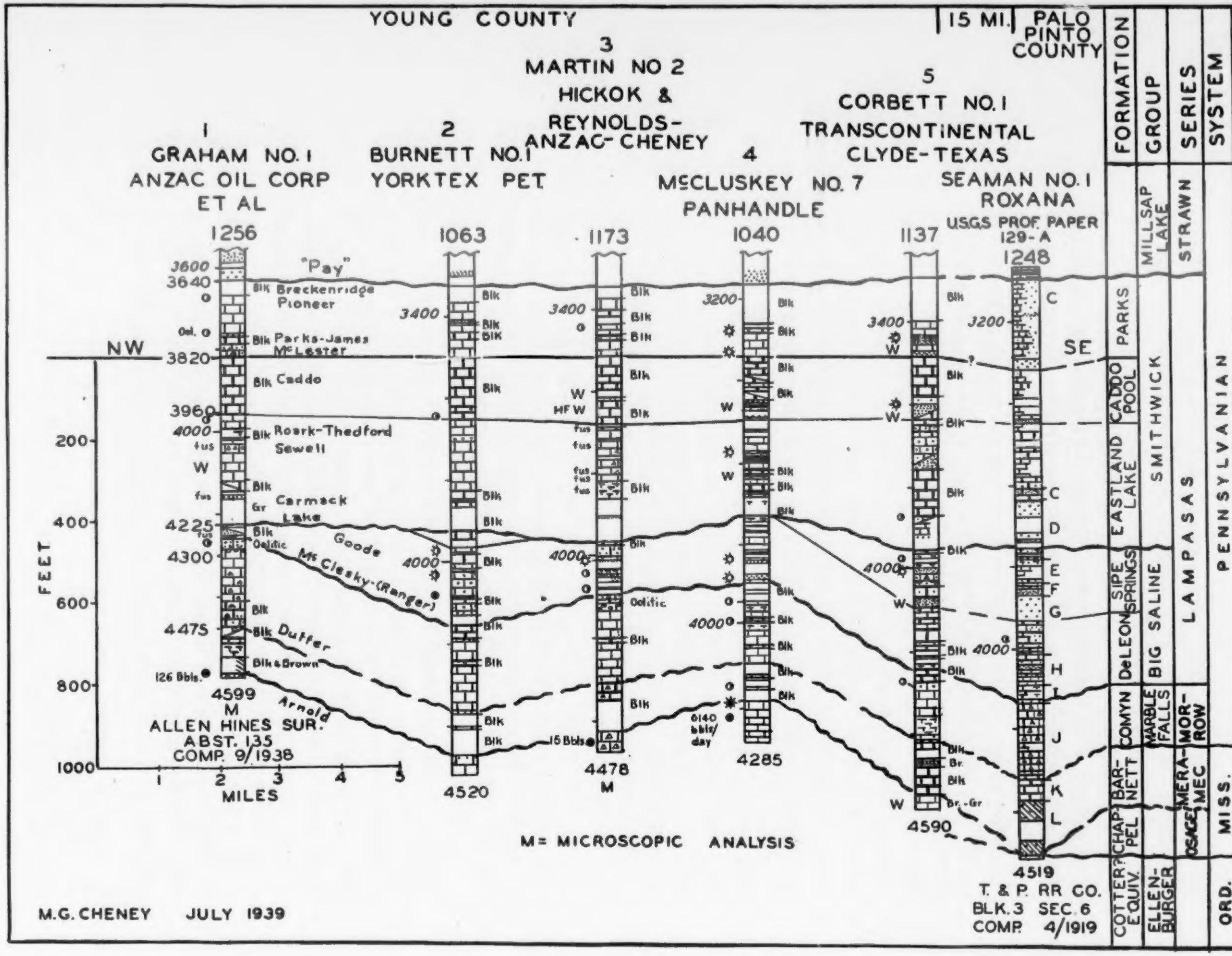


FIG. 5.—Formations of Smithwick, Big Saline, and Marble Falls groups. Seaman No. 1 is referred to for type section of Comyn, De Leon, and Sipe Springs formations, and Graham No. 1 for Eastland Lake, Caddo Pool, and Parks formations. Location of wells 1–5 shown in Figure 10.

northward in subsurface they attain a thickness of at least 400 feet in the Ranger area and are divisible into two formations as shown in Figure 5, each formation having a sequence of sand and shale followed by limestone. Cuttings of the Roxana Petroleum Company's Seaman No. 1 test in northwest Palo Pinto County are taken as the type subsurface section of the Marble Falls and Big Saline groups. These samples were the subject of an exhaustive lithologic study by Goldman[21] and are no doubt on file with state and national geological surveys. That portion of the Marble Falls which occurs in the Ranger area is herein called the *Comyn* formation. The lower and upper sequences of sand and shale followed by limestone of the Big Saline group of the Ranger area are herein named the *De Leon* and *Sipe Springs* formations. These three formation names are derived from towns in northern Comanche County. Eastward gradation to shale seems to account for the step-like arrangement whereby thick limestone beds are encountered at successively lower stratigraphic positions in the vicinity of these towns. Such gradation in the Sipe Springs formation can be conclusively shown by wells in the oil field southwest of Carbon in central Eastland County and in the gas field east of Santa Anna in Coleman County, these oil and gas accumulations being controlled, in part, by such changes in lithology. Prior to Smithwick time, Sipe Springs beds were removed by erosion locally as is shown in Figure 5, and regionally as seen in Figures 2 and 4. Formational boundaries in the two wells described by Goldman are placed as follows.

Formation	*Seaman No. 1* *Feet*	*Rudd No. 1* *Feet*
Sipe Springs	3,760–3,870	2,490–2,619
De Leon	3,870–4,132	2,619–2,841
Comyn	4,132–4,320	2,841–2,963

In the type log of the Ranger district of the Plummer and Moore report,[22] the Sipe Springs formation includes limestone "D" ("Ranger lime pay") and underlying shale; the De Leon, limestone "C" and underlying shale; and the Comyn formation, the beds below "B" which coalesce into a continuous 200-foot limestone section over much of this region.

The Smithwick beds are excluded from the Morrow and Strawn (Des Moines) series and assigned to an intervening Lampasas series

[21] Marcus I. Goldman, "Lithologic Subsurface Correlation in the 'Bend Series' of North-Central Texas," *U. S. Geol. Survey Prof. Paper 129A* (1921), Pl. I.

[22] F. B. Plummer, R. C. Moore, "Stratigraphy of the Pennsylvanian Formations of North-Central Texas," *Univ. Texas Bull. 2132* (1921), p. 40, Fig. 5, column 1 (not column 2).

for reasons previously discussed. Three mappable formations are discernible in the Smithwick beds of the Bend flexure area where the Smithwick has become mainly limestone interbedded with various local and generally thin shale and sandstone members. As in the case of the Marble Falls, the sequence of sandstone and shale followed by limestone is repeated at least three times where this 600-foot Smithwick section is typically developed as in central Stephens and Young counties.[23]

The lowest formation of the Smithwick is termed the *Eastland Lake* formation and includes the Lake and Carmack productive sandstone members in the lower part, and the Sewell and Roark or Thedford limestone "pays" in the upper part. Fusulinids are relatively abundant in the gray limestone members of this formation which is named from the Eastland Lake district of northwest Eastland County.

About 200 feet of dense black spicular limestone forms the major part of the second formation, some thin sandstones being present in the lower part. The discovery well of the Caddo pool of eastern Stephens County was completed in this black limestone, which is colloquially but widely known as the "Caddo lime" or "Caddo pay"; hence the name *Caddo Pool formation* is proposed for this division, the name *Caddo* being pre-occupied. In some areas the term "Caddo lime" has been applied to all limestone of Smithwick age.

A third formation of the Smithwick group is designated the *Parks* formation, named for the town of Parks and the Parks lease on which the first Smithwick production was found in central Stephens County. The basal member of this formation is the productive sandstone known as the McLester "pay" of south-central Young County. Productive gray or brownish limestones of the Parks and James pools overlie this sandstone and near the top of the formation occurs the important gray limestone "pay" of the Breckenridge, Eliasville, Ibex, and Pioneer pools. The eastern margin of the gray limestones of the Parks formation follows a southeast course from central Young

[23] Well cuttings from the Anzac Oil Corporation *et al.* E. S. Graham No. 1, located in the Allen Hines Survey, Abstract 135, central Young County, have been filed with the Bureau of Economic Geology, University of Texas, and the United States Geological Survey to serve as a type section for these formations of the Smithwick group. In this well the Parks formation includes the beds from depths of 3,626 to 3,820 feet; Caddo Pool formation, 3,820 to 3,960 feet; and the Eastland Lake formation, 3,960 to 4,225 feet. General lithologic sequence of these formations is shown for several wells of south-central Young County in Figure 5. The character of the Smithwick and Marble Falls beds has been given in detail in many past reports, especially those by Goldman (see previous citation) and Frank E. Kendrick and Phillip G. Russell in "Natural Gas in the Bend Arch District of Texas," *Geology of Natural Gas* (Amer. Assoc. Petrol. Geol., 1935), pp. 609–649.

County to an area a few miles northwest of Caddo in Stephens County, whence it trends southwestward for about 40 miles to northeast Callahan County. Here a south-southeast course is resumed to the Cross Cut pool of northern Brown County where the trend again changes to south-southwest for about 50 miles to eastern McCulloch County. The entire Smithwick section must have been removed by erosion in southern McCulloch County and vicinity prior to or during early Strawn times, for the Rochelle conglomerate of the Garner or older formations is in contact with Big Saline limestones as seen at Soldiers' Water Hole, 3 miles south-southwest of Rochelle in Survey 239.

As indicated in Figure 4, the "boulder bed" member of the Haymond deposits in the Marathon area may represent the results of extensive orogeny at the close of Lampasas time. As shown by King,[24] this exceptional member with erratic boulders, some of them 100 feet in length, attains a thickness of 900 feet in some localities.

STRAWN AND CANYON SERIES

It is proposed to drop the name Strawn group and to use the name *Strawn series* for the deposits occurring above the unconformity at the top of the Smithwick and related beds of the Lampasas series and below the unconformity or disconformity which separates the Lake Pinto sand from the East Mountain shale at Mineral Wells. This places the upper boundary above the highest occurrence of *Mesolobus* and *Fusulina*, ss., which characterize the Des Moines but are absent in the overlying Missouri series of the northern Mid-Continent. Unfortunately this upper boundary falls within the Mineral Wells formation of earlier reports, both lower and upper divisions of which have furnished important described faunules.[25] This requires readjustment of former classifications and occasions needed expansion of rank of certain divisions and rearrangement of others. Suggested changes of classification are set out in Figure 1. Most of the Strawn and Canyon beds named in this table have established usage and described faunas in the extensive report on the geology of Palo Pinto County by Plummer and Hornberger.[26] An effort has been made to change as few names as possible. Current usage is followed where confusion exists in past reports, as in the case of Palo Pinto formation. The only name dropped is that of the Mineral Wells formation.

[24] Philip B. King, "Geology of the Marathon Region, Texas," *U. S. Geol. Survey Prof. Paper 187* (1937), Pl. 8.

[25] F. B. Plummer and J. Hornberger, Jr., "Geology of Palo Pinto County," *Univ. Texas Bull. 3534* (1935).

[26] *Ibid.*

The Millsap Lake, Graford, Brad, and Caddo Creek divisions are considered groups instead of formations. The beds between the Millsap Lake and Graford (restricted) groups are herein divided into two groups, a lower *Lone Camp* group and an upper *Whitt* group with common boundary at the disconformity between the Strawn and Canyon series as noted above.

The Lone Camp group is named from the village of Lone Camp located about 12 miles southwest of Mineral Wells on the dip slope of the Brazos River conglomerate. The Garner and East Mountain shale formations comprise this group. The term Lone Camp limestone appeared in the Parker County, Texas, outcrop map in 1930, but did not come into common usage because this thin limestone had been named the Dog Bend limestone on the Palo Pinto County outcrop map published in March, 1929; both maps were published as preliminary editions by the Bureau of Economic Geology, University of Texas.

The Whitt group is named from the village of Whitt in northwest Parker County near which beds of Palo Pinto, Keechi Creek, and Salesville formations appear from beneath Comanche overlap. The Whitt group is nearly equivalent to the Brownwood shale. The northern area offers the better type locality with its more complete section.

The rank of formation is suggested for the following units which have been defined in earlier papers as members: East Mountain shale, Salesville (expanded below to base of Lake Pinto sandstone), Keechi Creek (expanded below to base of Turkey Creek sandstone), Palo Pinto (expanded above to top of Wiles limestone and below to base of subjacent sandstone), Adams Branch (Staff, expanded below to include shale and sandstone section about 50 feet thick above the Wiles limestone member), Cedarton shale, Winchell ("Clear Creek," Merriman limestone member at top), Placid shale, Ranger limestone, Hog Creek shale, and Home Creek limestone. The last mentioned formation is redefined to include shales found locally above the highest limestone member of the Home Creek formation and below the disconformity at the base of the Cisco.

The lower limestone member of the Palo Pinto formation is herein called the *Wynn* limestone from the locally well known landmark, Wynn Mountain, 2½ miles east of the town of Palo Pinto. Over a large area in the subsurface, the Wiles limestone, Posideon shale and limestone and Wynn limestone form a 200-foot limestone now commonly known as the Palo Pinto formation,[27] the upper part probably

[27] F. B. Plummer and J. Hornberger, Jr., *op. cit.*, Fig. 6, p. 73.

being the important "Palo Pinto pay" of Jones and Shackelford counties.

The Canyon series includes the sediments occurring above the disconformity (unconformity in the more positive areas) at the base of the Lake Pinto sandstone member at Mineral Wells up to the beds deposited prior to the disconformity marked by the Kisinger channel of southeast Young County.[28] This subdivision is thought to be approximately equivalent to the Missouri series of Kansas. It is distinguished lithologically by relatively thick limestone deposits which developed locally in bioherm or reef-like form as may be noted in subsurface particularly in Taylor County (Fig. 4); over the Electra arch in Wichita County (Fig. 2); also at the outcrop in western Wise County.[29] Thick sand bodies and pronounced thinning occur more or less locally in the Cedarton (Wolf Mountain) shale formation near the middle of the Canyon series. As measured in wells near the Brazos and Colorado rivers, the Canyon beds above the Winchell limestone are 400 and 250 feet thick, respectively, and those below this datum, 1,200 and 450 feet.

Primitive thin-walled species of the genus *Triticites* are found in the Canyon series in and especially below the Palo Pinto limestone.[30] *Triticites* cf. *nebraskensis* occur in so great abundance as to form a thin limestone about 60 feet below the Adams Branch limestone in the area west of Brownwood. Similar development has been noted in southern Eastland County and apparently occurs above the Palo Pinto formation at least as far north as west-central Palo Pinto County along U. S. highway 80, 1.4 miles east of Metcalf. About 200 feet higher a much larger form, *Triticites neglectus*, is found locally abundant in Eastland and Palo Pinto counties. *Triticites neglectus* occurs as low as the Adams Branch west of Brownwood.

Lee's recommendation is followed whereby the name *Winchell* is applied to the several limestone members which were originally called "Clear Creek" by Drake and "Merriman" by later writers. These limestone members coalesce into a thick massive limestone in the subsurface. Early miscorrelations of the Rochelle conglomerate, Capps and Adams Branch limestones between their type localities

[28] Wallace Lee, C. O. Nickell, J. S. Williams, and Lloyd G. Henbest, "Stratigraphic and Paleontologic Studies of the Pennsylvanian and Permian Rocks in North-Central Texas," *Univ. Texas Bull. 3801* (1938).

[29] Gayle Scott and J. M. Armstrong, "The Geology of Wise County, Texas," *Univ. Texas Bull. 3224* (1932), p. 28.

[30] The occurrence of *Triticites* sp. *A* below Lake Pinto sandstone remains in doubt, the material reported by Maynard P. White in *Univ. Texas Bull. 3211* (1932), p. 78, was possibly mislabeled as to locality.

in the Colorado River district and the Brazos River district should be borne in mind in using the early literature. The Rochelle conglomerate may be traced northward below the Capps limestone, hence is now considered at least as old as the Brazos River conglomerate.

The writer is inclined to disagree with recent proposed changes of correlation of upper Canyon and lower Cisco limestone near the type Home Creek locality of southeast Coleman County. It is believed that errors near Byrd's store in the outcrop map of Brown County and the writer's misinformation given Lee as to the location of a certain well led to an incorrect interpretation by Lee and others.[31] The numerous well logs of this district support the earlier interpretations.

CISCO SERIES

The Cisco series includes the Pennsylvanian sediments above the widespread disconformity which followed deposition of the Home Creek limestone members. The Cisco is intended to be the approximate Texas equivalent of the Virgil series of the northern Mid-Continent region, although neither basal nor top boundaries as now drawn may be exactly equivalent. The short-ranged *Triticites beedei, T. moorei*, and *T. plummeri* of the Shawnee and Wabaunsee groups of Kansas occur in the upper Graham and Thrifty groups. The complex Graham and Thrifty (expanded) beds are given group rank as major divisions of the Cisco series. It appears desirable to subdivide the numerous lithologic sequences of the Cisco and later series into formations, each to take its name from its most prominent member or by numbered cycles as designated by Lee and others. The Kisinger channel[32] at the base of the Graham group records local erosion at least 150 feet deep into the Home Creek and Hog Creek beds. A red shale interpreted as a zone of weathering occurs above the Home Creek limestone over much of the region. On certain structures the upper members of the Home Creek formation were eroded as in the western part of the Overall field of Coleman County.

The Graham group of early Cisco time shows much more variation in thickness than any other Cisco subdivision. In contrast to the underlying Canyon and Strawn beds the Graham formation thins toward the southeast, a thickness of about 600 feet in southern Archer County changing to about 300 feet in northeast Jack County and from 300 feet in western Coleman to 100 feet or less in southeast Coleman County. This suggests renewed uplift and orogeny of the Ouachita-Marathon Mountain range. The abundance of coarse ma-

[31] Wallace Lee *et al., op. cit.*, pp. 108–18 and Pl. VIII.

[32] *Ibid.*, pp. 12–16, Pls. 1 and 4.

terial in the Cisco and succeeding beds gives depositional evidence of the progressive growth of the Arbuckle, Wichita and Amarillo mountains to the north during Cisco time; also the Ouachita-Marathon orogeny evidently became active during Cisco time. Beds bearing Graham fauna, involved in folding and overthrusting in the Marathon district, were eroded and overlapped by Lower Permian marine deposits in the area of the Glass Mountains.

As will be discussed in more detail under Permian System, the upper boundary for the Cisco series and the Pennsylvanian system evidently should be placed at some widespread disconformity in the Harpersville formation above the Waldrip-Newcastle coal[33] zone and below the *Schwagerina*-bearing "Waldrip limestone No. 3" and the Saddle Creek limestone.[34] The 125 feet more or less of shales with lenticular limestone, sandstone, conglomerate, and coal members underlying this systemic boundary and overlying the Chaffin formation are herein called the *Obregon formation*, named from Obregon Switch on the Gulf, Colorado, and Santa Fe Railroad, 6 miles east of Santa Anna, Coleman County. The Obregon formation evidently includes more than one cycle. Below this formation lies the Chaffin formation with its upper thin limestone member about 20 feet above a thicker limestone member, both fusulinid-bearing, over shale and a basal Parks Mountain sandstone member. Beneath this are the Breckenridge and Speck Mountain formations. The limestone member at the top of the Speck Mountain formation has the lithologic appearance of the widespread Blach Ranch limestone of the Brazos River section whereas the limestone beds of the Chaffin formation resemble the Crystal Falls limestone beds of the Brazos River area. The intervening Breckenridge formation occurs where not removed by erosion which preceded deposition of the Parks Mountain sandstone.[35]

As thus defined, the Permian-Pennsylvanian boundary is 40–150 feet below the Saddle Creek limestone. "Harpersville" beds below this boundary are assigned to the Obregon and Chaffin formations of the Thrifty group, those above this systemic boundary to the Saddle Creek formation of the expanded Pueblo group.

As thus constituted, the Cisco series is several hundred feet thinner than the Virgil series. This may be due to the presence of more numer-

[33] It is not known whether all or only part of this 120-foot coal-bearing zone was considered upper Monongahela by David White. F. B. Plummer and R. C. Moore, *op. cit.*, p. 168.

[34] Using correlation of Saddle Creek limestone as shown on Plate VI of *Univ. Texas Bull. 3801*, not as on preliminary "Geologic Map of Young County, Texas," *Bur. Econ. Geol.* (1930).

[35] Wallace Lee *et al.*, *op. cit.*, Pl. VIII.

ous disconformities and less continuous deposition or to an absence of the uppermost Pennsylvanian as compared with the northern Mid-Continent. This is not surprising in view of the proximity to areas of late Pennsylvanian orogeny which practically encircled the north-central Texas area.

FORMATIONS VERSUS MEMBERS

The problem of appropriate name and rank for the innumerable beds of the Pennsylvanian and Permian systems in this area is not easily solved. Classifying these beds by systems, series, groups, formations, members, and individual beds according to recent interpretations of these terms[36] permits revisions of rank for many of the units of north-central Texas to meet present needs in preparing detailed stratigraphic and structural maps. For instance, previous reports have treated the East Mountain shale as of member rank. These beds vary in thickness from about 50 feet in McCulloch County to 550 feet in Parker County and, as traced laterally, contain thick limestones and sandstones, which, when given formal names, should themselves be called members. Changing the East Mountain shale "member" to formational rank makes possible the naming of important members, such as the Village Bend limestone. The sequence of limestones above shale and sandstone members observed in the East Mountain shale formation is repeated many times in the Pennsylvanian and Lower Permian sediments. These sequences constitute "the fundamental units in the local classification of rocks" in this region and commonly form distinct mappable formational units. Such units are listed in Figure 1 as formations, each named from some well known member, thus avoiding numerous new names. The limits of these formations will be generally recognizable in field work and are not thought to require description beyond that already contained in geological literature of the area. The following condensed section from the vicinity of Coleman Junction (now called San Angelo Junction on railroad maps), Coleman County, may serve as an example of these member and formational sequences, closely duplicating, except as to thickness, the sequence of sandstone, shale, and limestone deposition noted in the East Mountain formation in its type area.

	Thickness in Feet
Shales and sandstone (Fisk formation)	36
Hords Creek formation	
Limestone, upper (No. 3)	10
Shale	20

[36] "Classification and Nomenclature of Rock Units," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23 (1939); R. C. Moore, "Stratigraphic Classification of Pennsylvanian Rocks of Kansas," *Bull. Univ. Kansas*, Vol. 36, No. 22 (1936).

Limestone, middle (No. 2)	8
Shale, thin-bedded cherts	8
Limestone, lower (No. 1)	6
Shale, sandstone lenses	35
Coleman Junction formation	
Limestone, upper (No. 2), abundant fusulinids (including *S. emaciata*) in upper half, brachiopods in lower half	4
Shale	5
Limestone, lower (No. 1), cherty, thin-bedded	10
Shale, some bright to dark red, sandstone lenses	50
Santa Anna Branch formation: shales with limestone members in upper part	

This section serves to illustrate the point that, if innumerable names are to be avoided in naming the relatively unimportant individual members of these many cyclic formations, sanction must be given to the usage of such designations as "upper," "middle," or "lower," or of numbers. It is recalled that the same name is not to be applied to both a formation and a member thereof; hence, according to present rules, if the suggested usage of position or number designation is followed, the expression should be, for example, limestone No. 3 (or upper limestone) of the Hords Creek formation and not Hords Creek limestone No. 3. If deemed necessary, compliance with this requirement as well as the use of quotation marks appears preferable to a profusion of member names.

Some divisions herein called formations lack the typical triple lithologic sequence throughout much of this region. These formations are composed mainly of limestone or of shales with interbedded hard members with total thickness approaching or exceeding 100 feet. Since units of this thickness occupy generally more than one mile width of outcrop in this region of low dips, they are readily charted on a map having a scale of one mile to the inch. For instance, in the Coleman area the Elm Creek limestone consists of a large number of members of varying character and faunal content, some dolomitic and some cherty, separated by a variety of shales, making up a total thickness of 80 feet. At least twelve bench-forming members are present, about half of which must be used in detailed plane-table mapping of the area of outcrop one to 3 miles wide. This thick sequence of limestone as well as the underlying 100–120-foot shale section with its several members of limestone, sandstone, coal, and different shales appears deserving of formation rank.

Use of formational rank for these sequences and for thick divisions mostly limestone or shale necessitates designating as groups certain useful combinations of these divisions. Thus, in addition to changes previously mentioned, the Graham, Thrifty (expanded), Pueblo (expanded), Moran, Putnam, Admiral (restricted), Belle

Plains (expanded), Clyde, and Lueders formations of earlier reports are herein considered as groups.

PERMIAN SYSTEM

WOLFCAMP SERIES

The selection of a Pennsylvanian-Permian boundary in north-central Texas has presented much difficulty, perhaps because of the rather large number of disconformities and much overlapping of faunas. It is assumed that the very pronounced unconformity accompanied by considerable faunal change at the base of the Wolfcamp in the Glass Mountains establishes this as the logical Pennsylvanian-Permian boundary for the United States. Two higher breaks are used by some European geologists, but three of the six Russian papers given at the International Geological Congress in 1937 place the Sakmarian (Wolfcamp fauna) in the Permian.

In north-central Texas, the boundary will necessarily be chosen above the *Uddenites* zone of the Graham group and doubtless above the Waldrip-Newcastle coals of the Obregon formation. The fauna of the Saddle Creek formation (upper "Harpersville") show notable changes[37] in the brachiopods,[38] pelecypods, crinoids, bryozoa, and fusulinids. The new forms have a definite Permian aspect. Romer[39] considered the Pueblo formation as of Wolfcamp age based on the presence of the common vertebrates of the Wichita group in the Pueblo.

Mainly on the basis of the presence of "Schwagerina," now *Pseudoschwagerina*, in the upper Horse Creek limestone of the Moran beds, Sellards in 1932[40] proposed lowering the Permian boundary from the Coleman Junction to the top of the Camp Colorado limestone. "Pseudofusulina," now *Schwagerina* Dunbar and Skinner 1936, reported by Roth[41] about 20 feet below the base of the Saddle Creek limestone in Drake's Waldrip Bed No. 3 and at least 150 feet above the Chaffin (Crystal Falls) beds, was not then accepted as necessarily indicative of the Permian. This genus is now considered of Permian age to the same degree as Sakmarian and Wolfcamp are Permian. Similar forms

[37] F. B. Plummer and R. C. Moore, *op. cit.*, pp. 166, 168.
Wallace Lee *et al.*, *op. cit.*, pp. 212, 215.

[38] R. H. King, "New Chonetidae and Productidae from the Pennsylvanian and Permian Strata of North-Central Texas," *Jour. Paleon.*, Vol. 12, No. 3 (1938), p. 258.

[39] A. S. Romer, "Early History of Texas Redbed Vertebrates," *Bull. Geol. Soc. America*, Vol. 46 (1935), p. 1624; also Fig. 3.

[40] E. H. Sellards, *Univ. Texas Bull. 3232*, p. 172.

[41] Robert Roth, "New Information on the Base of the Permian in North-Central Texas," *Jour. Paleon.*, Vol. 5 (1931), p. 295.

occur 30 feet above the Saddle Creek limestone in northern McCulloch County[42] and have been reported from well cuttings of Saddle Creek limestone from other areas. The gray limestone member (above the *Uddenites* zone) at the base of the Wolfcamp series of the Glass Mountain section now considered Permian by King[43] contains similar schwagerinid forms and is succeeded by a brown limestone carrying *Pseudoschwagerina*. The thick red shales occurring in the Pueblo group appear more Permian than Pennsylvanian. Arkosic material, which is rarely if ever present in the sandstones of the Canyon and Cisco series, appears in abundance just above the Saddle Creek limestone, as for instance, near the northwest corner of the Allen Hines Survey in west-central Young County.

From this evidence it appears that the Pennsylvanian-Permian boundary should be lowered from the base of the Moran formation to the first widespread unconformity below "Waldrip limestone No. 3," probably at least 30 but less than 150 feet below the top of the Saddle Creek formation. The exact position of this major break is tentatively placed below the "Waldrip limestone No. 2" because of the frequency of irregular deposition noted in subsurface in this part of the section. On a southward projecting point one mile southwest of Rockwood, this boundary is tentatively placed beneath a sand and thin coal deposit about 20 feet below "Waldrip limestone No. 2." This places "Waldrip limestone No. 1" with its abundant upper Cisco fusulinids as the upper limestone member of the Obregon formation of the Thrifty group.

In determining the upper limits of the Wolfcamp series it is first necessary to redefine the formations at the boundary. The names "Bed No. 5" of Drake and "Coleman limestone" of Plummer and Moore, need replacement by a geographic name and an unpreoccupied name. The name *Fisk formation* is therefore proposed for the limestones and underlying shales and sandstones ("Indian Creek bed" of Drake) that occur above the Hords Creek formation and below the disconformity at the base of the Jim Ned shale. The name is derived from the village of Fisk located about 12 miles southwest of Coleman on the upper limestone members of this formation. The upper limestone and lower shale members were adequately described by Drake.[44] Wells near Fisk show a thickness of about 40 feet of

[42] F. M. Bullard and R. H. Cuyler, "The Upper Pennsylvanian and Lower Permian Section of the Colorado River Valley, Texas," *Univ. Texas Bull. 3501* (1935), p. 245.

[43] P. B. King, "Geology of the Marathon Region," *U. S. Geol. Survey Prof. Paper 187* (1937), p. 95.

[44] N. F. Drake, "Report on Colorado Coal Field of Texas," *Univ. Texas Bull. 1755* (1892; reprint 1917), p. 56.

limestone with thin shale partings, overlying 50–60 feet of shale with lenticular sandstones in the lower part. The upper limestone members become thinner and shale partings more numerous toward the north.

The name *Jim Ned shale* is proposed to replace Drake's "Coleman bed," the name Coleman being preoccupied. The proposed type locality is in the south part of the Newschaffer Survey No. 750 just west of the highway bridge over Jim Ned Creek on the Coleman-Baird highway about ten miles north of Coleman. These beds, 100–125 feet thick, underlie the Elm Creek limestone and extend downward to a disconformity noted in this district at the top of the Fisk formation. This disconformity is especially well seen where the Oplin-Cross Plains road crosses Pecan Bayou 8 miles north and 2 miles east of this type locality. Channel sandstone deposits and sandstone lentils (becoming more prominent northward), sandy shales, thin lignitic coals and black shales with abundant plant remains and thin limestone beds constitute the lower half of the Jim Ned shale. These are succeeded by green and reddish shales with thin dolomitic members in the upper part. The disconformity at the base of the Jim Ned shale is thought to mark the Wolfcamp-Leonard boundary, hence both the Elm Creek limestone and the Jim Ned shale are assigned to the Belle Plains group instead of the Admiral group as heretofore.

It appears necessary to place the top of the Wolfcamp series above the *Artinskia adkinsi* zone[45] of the Fisk formation. The top of the Fisk formation is normally about 200 feet above the Coleman Junction limestone in central Coleman County. There is more evidence of important disconformity between the Fisk formation and the overlying Jim Ned shale than is known by the writer at any other position in this part of the section below definite Leonard beds. Dissimilarity in structural contours based on the Elm Creek above and the Fisk formation below this disconformity has been noted in plane-table mapping in northern Coleman County. Measured sections on outcrop maps from Coleman to Baylor counties[46] show greater change of interval between these Elm Creek and Fisk limestone formations than for any other part of the Lower Permian section. At the outcrop and for many miles west thereof, dolomitic beds become an important part of the Elm Creek and higher beds but are rarely present below. Certain lower Leonard forms, such as *Stafella lacunosa*, are reported at 2,450 feet in the Plymouth Oil Co., Hanna No. 1 (H. & T. C. R. R. Co. Block 1-A, Section 2520), in northeast Coke County from a lime-

[45] F. B. Plummer and Gayle Scott, "Upper Paleozoic Ammonites in Texas," *Univ. Texas Bull. 3701* (1937), pp. 22, 95.

[46] Prepared by the Bureau of Economic Geology, University of Texas.

stone which the writer believes to be Elm Creek. The anhydrite zone of the lower Leonard in the Thompson Elsinor Cattle Co., No. 1 (G. C. & S. F. R. R. Co. Block D, Section 53, Pecos County) near the Glass Mountains may prove correlative with the widespread anhydrite zone occurring in the Valera beds 100–200 feet above the Elm Creek limestone. Beds thus included between the first regional disconformity below "Waldrip limestone No. 3" and above the Fisk formation are herein referred to as the Wolfcamp series. However, a somewhat higher Wolfcamp-Leonard boundary is suggested by Elias[47] who would place it at the top instead of the base of the Belle Plains group. Also, Miller[48] considers *Perrinites cumminsi* from the Clyde group as intermediate between known Wolfcamp and Leonard faunas. Romer[49] advocates the base of the Clyde as the lower boundary of the Clear Fork and Leonard beds based on extinction of some common vertebrates at this horizon.

LEONARD SERIES

Both on the basis of paleontological evidence and subsurface mapping, the outcropping beds in north-central Texas above the Wolfcamp series and below the Whitehorse group are correlated with the Leonard series of West Texas and herein referred to by this name. With lower beds assigned to the Wolfcamp series and the upper beds to the Leonard series, the usefulness of the term "Wichita group" largely disappears.

To follow current trends in classification, the thick "members" of the former Wichita group are given formation rank and former formations changed to groups as shown in Figure 1.

For the region as a whole, the Clear Fork group as defined in earlier reports forms a natural lithologic group of the Leonard series. However, farther south and southwest, the thin limestones and dolomites of the Arroyo formation become thicker and may be easily confused with the underlying Lueders group.

The San Angelo sandstone formation at the base of the El Reno (San Andres) group seems to mark the beginning of a new depositional cycle. The unconformity at the base is not thought to be widespread basinward. *Perrinites* occurs both below and above this break.

On the east side of the Permian basin the name El Reno group appears to have priority and to be more appropriate on a facies basis

[47] Maxim K. Elias, "Correlation of Upper Carboniferous and Artinskian in Russia with American Late Paleozoic Rocks," *Proc. Geol. Soc. America for 1934* (1936), p. 371.

[48] A. K. Miller, personal communication, February 3, 1939.

[49] A. S. Romer, *op. cit.*, p. 1651.

than the recently proposed[50] San Andres group for beds of Leonard age from the base of the San Angelo sandstone to the top of the Dog Creek shale formation. In the Guthrie dolomite member of the latter formation are found the Leonard ammonites, *Eumedlicottia crotonensis* and *Perrinites hilli*.[51]

In the Marathon area there is a pronounced unconformity at the base of the Leonard.[52] The appearance of *Parafusulina*[53] as well as the distinctive *Perrinites* zone[54] indicates that the Leonard series is approximately equivalent to the Artinskian series of Russia. This series is placed at the base of the Permian by some leading Russian geologists.

In general during Leonard time, the Concho arch region was subsiding more than the Electra arch region as indicated by a somewhat thicker and more marine section. As correlated in Figure 4, pre-Whitehorse Permian beds increase from about 3,800 in Coke County to 5,400 feet or more along a northwest-southeast trend passing through Irion County. This is due in part to truncation and overlap of older beds by Whitehorse deposits.

POST-LEONARD DEPOSITS, WHITEHORSE GROUP

There appears to be a much greater change at the base of the Whitehorse group overlying the Dog Creek shales formation than at the base of the San Angelo. The Whitehorse beds record a distinct change of material and environment and lie unconformably over lower beds in the observable area of eastward outcrop.[55] Discussion of the character and correlations of these post-Leonard beds is left to those specializing in the geology of West Texas.

STRUCTURAL FEATURES

The structural features of north-central Texas, as well as the literature thereon, have been reviewed in much detail by van der Gracht[56]

[50] "The Midyear Meeting of the American Association of Petroleum Geologists," program (1938), El Paso, Texas, p. 31.

[51] F. B. Plummer and Gayle Scott, *op. cit.*, p. 21.

[52] P. B. King, "Geology of the Marathon Region of Texas," *U. S. Geol. Survey Prof. Paper 187* (1937), p. 97.

[53] C. O. Dunbar and J. W. Skinner, *The Geology of Texas*, Vol. III, Pt. 2, "Permian Fusulinidae of Texas," *Univ. Texas Bull. 3701*, p. 595.

[54] A. K. Miller, "Comparison of Permian Ammonoid Zones of Soviet Russia with Those of North America," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 8 (1938), pp. 1014–19.

[55] Robert Roth, "The Custer Formation of Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21 (1937), pp. 421–74.

[56] W. A. J. M. van Waterschoot van der Gracht, "The Permo-Carboniferous Orogeny in South-Central United States," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15 (1931), pp. 991–1057.

and Sellards.[57] Additional data permit further analysis at this time.

The unconformities shown by continuous wavy lines in Figure 1 represent positions of important regional structural adjustments in or near the north-central Texas region. The short wavy lines in the right-hand column represent the position of notable channeling and/or extensive deposits of coarse detrital material as noted in surface or subsurface studies.

PRE-CAMBRIAN

The most pronounced unconformity of this region is, of course, between the pre-Cambrian complex and the overlying nearly horizontal Cambrian beds.

Where seen in the Llano uplift, the pre-Cambrian includes many granite masses, some appearing as elongate domes between shattered gneissic and schistose rocks several miles thick. This irregular basement of igneous and metamorphic rocks evidently characterizes the pre-Cambrian of this entire region. In the eastern part of the Llano uplift area the folds in pre-Cambrian rocks exhibit a prevailing northwest structural trend but in the western part pronounced northeast structural trends are present. These intersecting structural trends are also represented in the younger beds of the surrounding area by numerous nearly parallel folds and faults many of which show progressive intermittent structural growth.

PRE-ORDOVICIAN

The thickness of Hickory sandstone is known to vary from 0 to 600 feet in this region. This may be due, in part at least, to uneven floor and non-deposition rather than to erosion of upper members. Loss of pre-middle Gasconade Ellenburger beds toward the Concho arch (Fig. 3) indicates that the development of this arch had begun by early Ordovician time.

PRE-MISSISSIPPIAN: CONCHO ARCH

Figure 3 demonstrates that, prior to Mississippian deposition, Cambrian and Ordovician deposits had been affected by regional uplift and truncation along a broad axis extending from the present Llano uplift northwestward for an undetermined distance. With extensive uplift established, this feature named from Concho County is more suitably referred to as the *Concho arch* rather than Concho divide.[58] According to available data, the Barnett and somewhat

[57] E. H. Sellards, "The Geology of Texas," Vol. II, *Univ. Texas Bull. 3401* (1934), Pt. 1, pp. 11–132.

[58] M. G. Cheney, "History of the Carboniferous Sediments of the Mid-Continent Oil Field," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13 (1929), p. 575.

older Mississippian beds are in contact with *middle* or *lower* Ellenburger beds in McCulloch, Taylor, and Fisher counties but rest on successively higher Ellenburger beds toward the east. A similar beveling of Ellenburger beds is indicated for the southwest flank of the Concho arch. However, in eastern Menard County and vicinity and in much of the area west and southwest of this area of greatest uplift, the Ellenburger is overlapped by Pennsylvanian rather than by Mississippian beds.

PRE-MORROW: LLANORIA-LOWER WICHITA OROGENY; OUACHITA-MARATHON BASIN

Contrary to prevailing tendency in the Ordovician and later Mississippian beds, there is an eastward loss of Chappel limestone in the region of the Bend flexure.

Thicker Mississippian sections indicate basin areas north and south of the Electra arch in Childress and Throckmorton counties. In Childress County arkosic material in the Upper Mississippian beds is indicative of initial phases of structural movements which van der Gracht[59] termed the Wichita orogeny.

Western loss of Barnett shale beneath Marble Falls beds in the areas between the Bend flexure and Concho arch adds to the evidence of some slight regional movements in this region while extensive troughs were being developed and filled with detrital material in the Ouachita-Marathon geosynclines and Ardmore basin. Llanoria and to some extent the foreland axes of the Concho and Hunton arches and the Central Kansas uplift were evidently being elevated sufficiently to supply the vast amount of detrital material which filled these deep basins during pre-Morrow time.

PRE-LAMPASAS: MIDDLE WICHITA OROGENY

As discussed under the heading "Morrow and Lampasas Series," the type Marble Falls limestone thins regionally toward the Concho, Electra, and Muenster arches, but it is not clear whether this is due to thinning or truncation. Very probably structural changes were affecting broad areas during and after Morrow time. Judging by evidence from the near-by Ardmore basin and Criner Hills,[60] it is quite possible that much greater deposition and folding took place in north-central Texas during this time than is now apparent, especially in the Electra and Muenster arches.

[59] *Op. cit.*, Table II, p. 1004.

[60] C. W. Tomlinson, "The Pennsylvanian System in the Ardmore Basin," *Oklahoma Geol. Survey Bull. 46* (1929).

A broad area westward from the Concho arch appears to lack Morrow beds, probably because of one or more post-Morrow-pre-Strawn uplifts. Correlations based on fusulinids show the Millsap Lake beds close to or in contact with Ordovician beds in western Tom Green, Irion, and Reagan counties[61] (Fig. 4).

PRE-STRAWN: UPPER WICHITA OROGENY; OUACHITA OROGENY; FORELAND ARCHING

Widespread submergence occurred during early Lampasas time and again even more extensively during later Lampasas time. The interruption between Big Saline and Smithwick deposition appears to have been important especially in the northern part of the area as indicated by Figure 5. The folding preceding Smithwick time is thought to be a third and somewhat later upper Wichita phase than that of van der Gracht.[62] Figures 2 and 4 show that Marble Falls beds were overlapped by the sandy, glauconitic Big Saline beds and the latter were in turn overlapped by the Smithwick.

During the post-Smithwick time pronounced geosynclinal developments in the Strawn basin and moderate upward movement of the Concho arch resulted in discordant dips of as much as 200 feet per mile between Smithwick and upper Strawn beds in the area east of the Bend flexure. Similar conditions probably developed in the Kerr basin southwest of the Concho arch. Furthermore, in the Concho arch and Strawn basin areas, local vertical movements in excess of 1,000 feet evidently developed in Smithwick beds prior to deposition of middle Strawn. These structural features appear more pronounced than those found between any other successive divisions of the Paleozoic section, and considered with the faunal changes heretofore discussed, seem to require placing the Smithwick in a separate pre-Strawn-post-Morrow division, herein referred to as the Lampasas series.

PRE-CANYON: CONCHO, ELECTRA, AND MUENSTER ARCHES; ARDMORE, STRAWN, AND KERR BASINS

Structural changes in north-central Texas just before and during Strawn time appear much more pronounced than during any similar epoch since the pre-Cambrian. The Concho, Electra, and Muenster arches must have taken on most of their present prominence between Lampasas and Canyon time.

[61] C. O. Dunbar, correspondence quoted, E. H. Sellards, *Univ. Texas Bull. 3401* (1934), p. 112.

[62] *Op. cit.*, Table II, p. 1004.

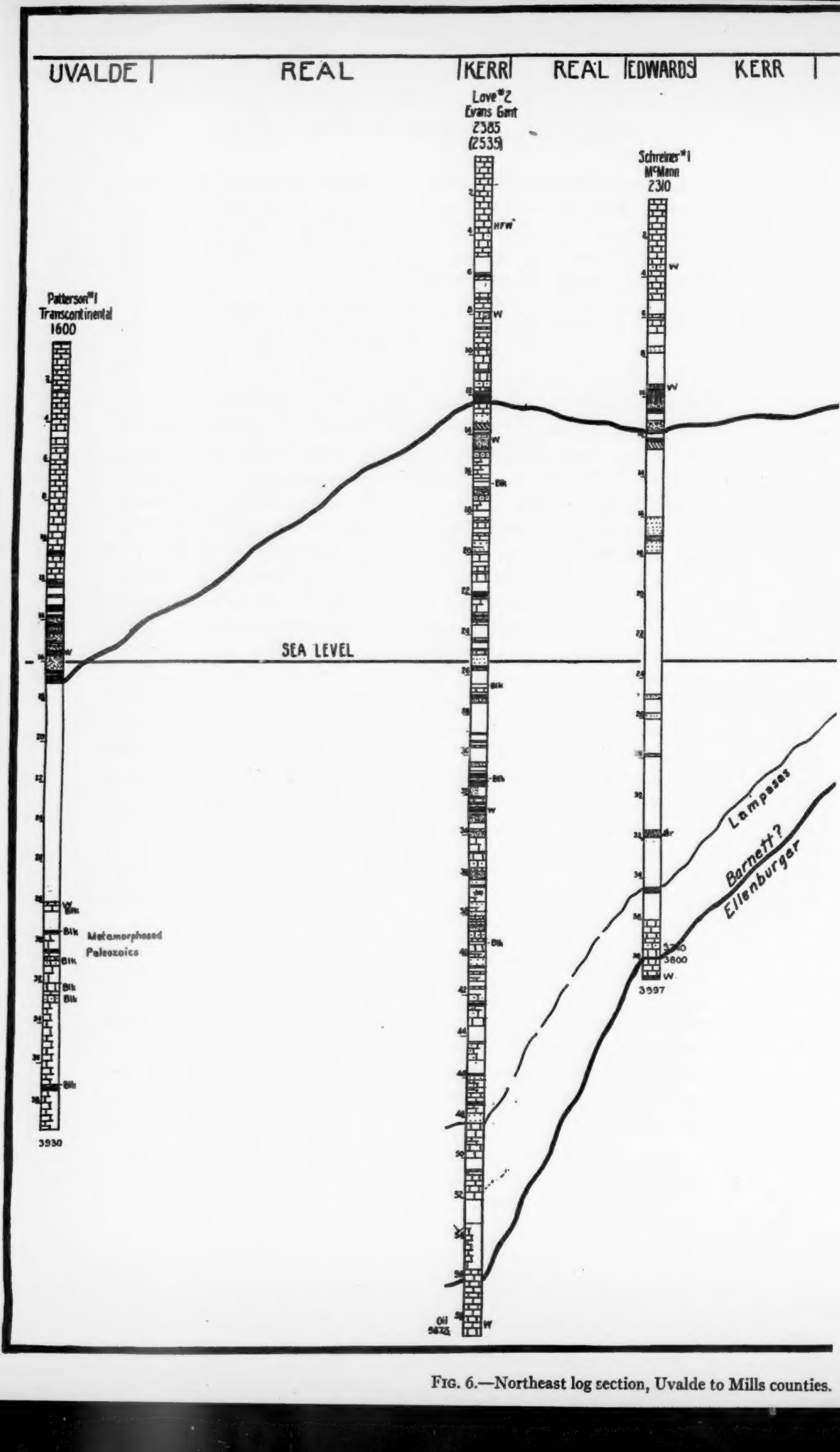
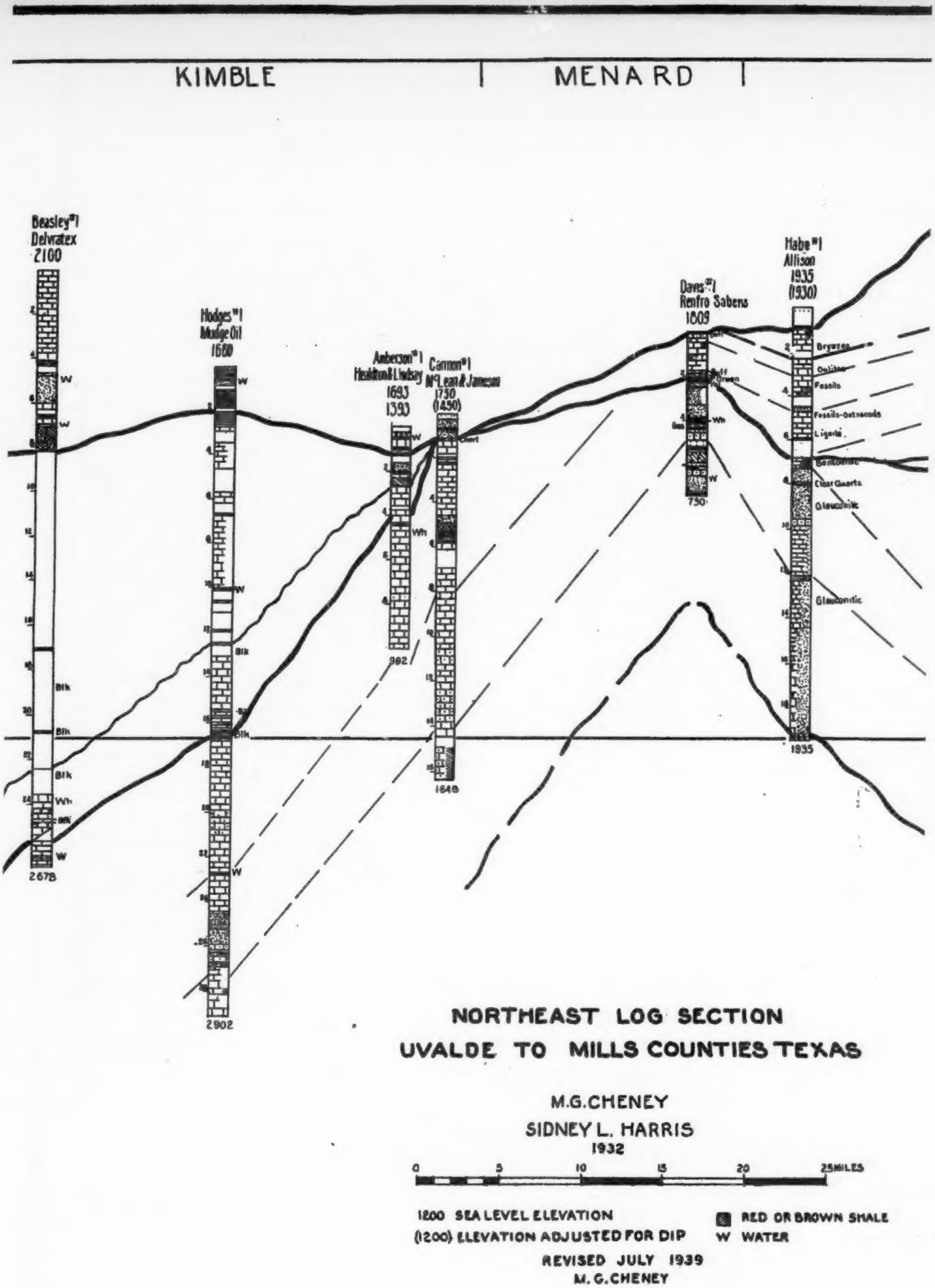


FIG. 6.—Northeast log section, Uvalde to Mills counties.



Sea-level rather than stratigraphic base line is used.

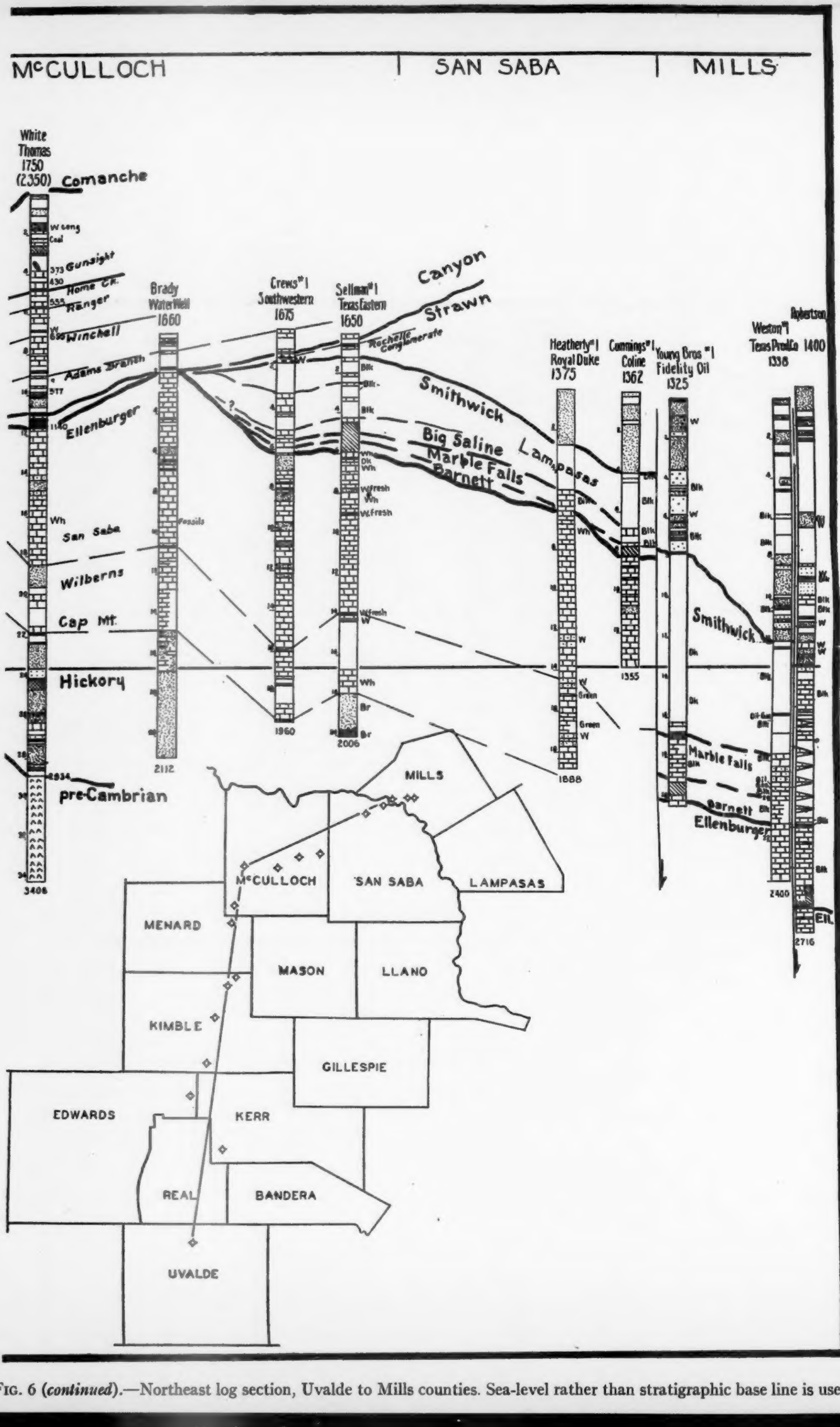


FIG. 6 (*continued*).—Northeast log section, Uvalde to Mills counties. Sea-level rather than stratigraphic base line is used.

As shown in Figures 2, 4, and 6, the Concho axis had by Canyon time become a dominant structural feature in central Texas and the area northwest thereof. By this time Upper Cambrian beds were doubtless at least 10,000 feet higher structurally on this arch than in the deepest parts of the flanking basins. This is shown roughly by the measured or estimated thickness of beds between the Winchell and San Saba formations as depicted in Figure 7. In preparing this map the regional dip of the Winchell limestone over an area 125 miles wide has been projected 50 miles eastward. The present position of the top of the San Saba formation is shown by Figure 8.

It is also evident from Figure 7 that a geosyncline connecting the Strawn, Kerr, and Marathon basins developed across the eastern part of the area of the present Llano uplift. Faults paralleling or extensions of those observed in the Llano uplift area have now been established by geophysical work and drilling for more than 100 miles toward the northeast into the Strawn basin area. Evidently these faults were the result of tension in the area marginal to a stable or rising foreland and flanking or within a deeply subsiding geosyncline. According to geophysical work, some of these normal faults have displaced Smithwick and older beds as much as 1,100 feet in the Strawn basin. This must have occurred mainly during the interval from late Lampasas to early Strawn times inclusive, for middle Strawn beds as seen in the Colorado River area near Regency are affected by only minor movements along a major fault line. This recalls somewhat similar conditions in southern Oklahoma where Morgan[63] found that vertical movement along the Stonewall fault amounted to about 3,500 feet between Wapanucka and late Boggy (about middle Strawn) time.

In the Llano uplift area most of these extensive crustal adjustments have the form of narrow, northeast-trending grabens lying between more stable areas. In San Saba County, the more prominent grabens may be named from the streams which traverse them, that is, the San Saba River, Wallace Creek, and Cherokee Creek. The towns of Richland Springs, Pontotoc, San Saba, and Lampasas are each located on or near the axis of one of the higher blocks which may be designated the *Richland Springs*, *Pontotoc*, *San Saba*, and *Lampasas* axes, respectively. These structural features are not considered deserving of the rank of arch because of their minor prominence. In general they are tilted segments of the Concho arch occurring between narrower blocks which have moved downward.

[63] George D. Morgan, "Boggy Unconformity and Overlap in Southern Oklahoma," *Bur. Geol. Cir. 2* (Norman, Oklahoma, 1924), p. 8.

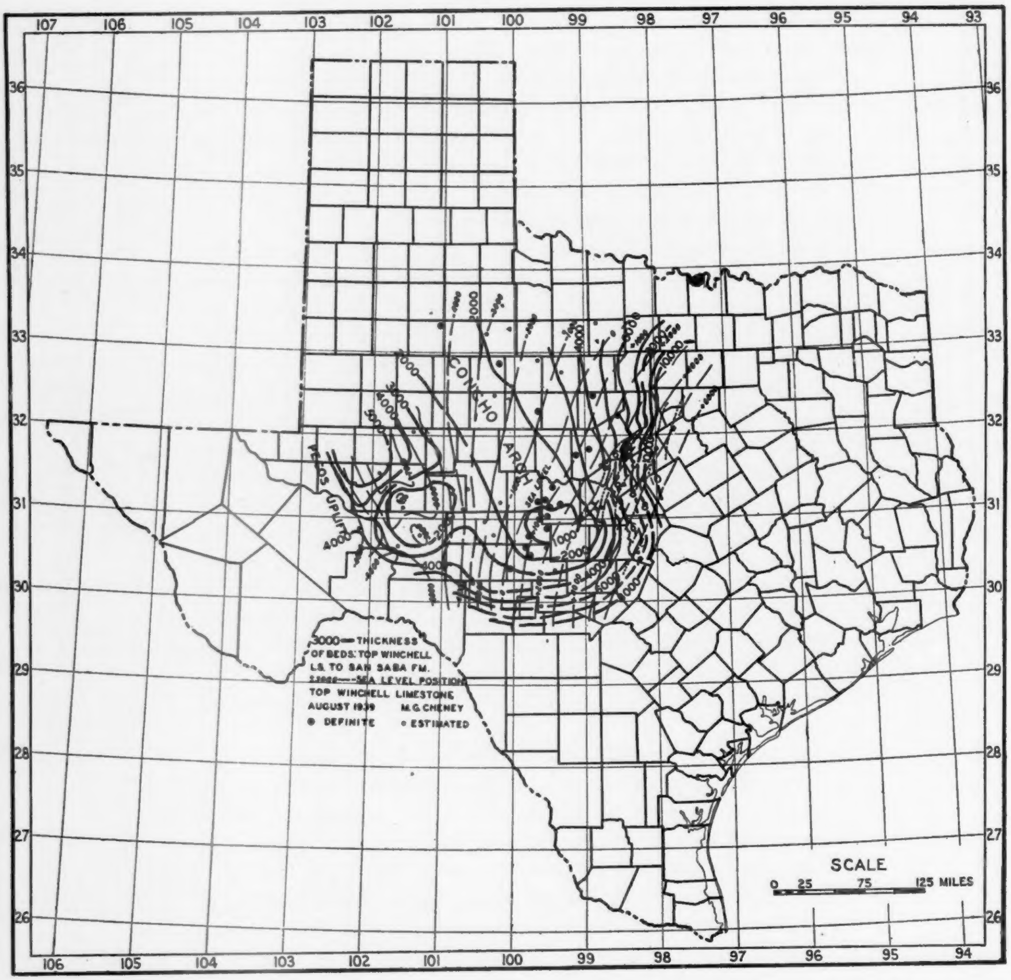


FIG. 7.—Approximate structural position of Cambrian beds during late Canyon time is revealed by thickness of beds from top of Winchell limestone to top of San Saba limestone shown by heavy lines. Net amount of westward tilting since Canyon time doubtless approximates westward dip of Winchell limestone shown by lighter lines (restored in areas approaching southwest extension of Ouachita uplift).

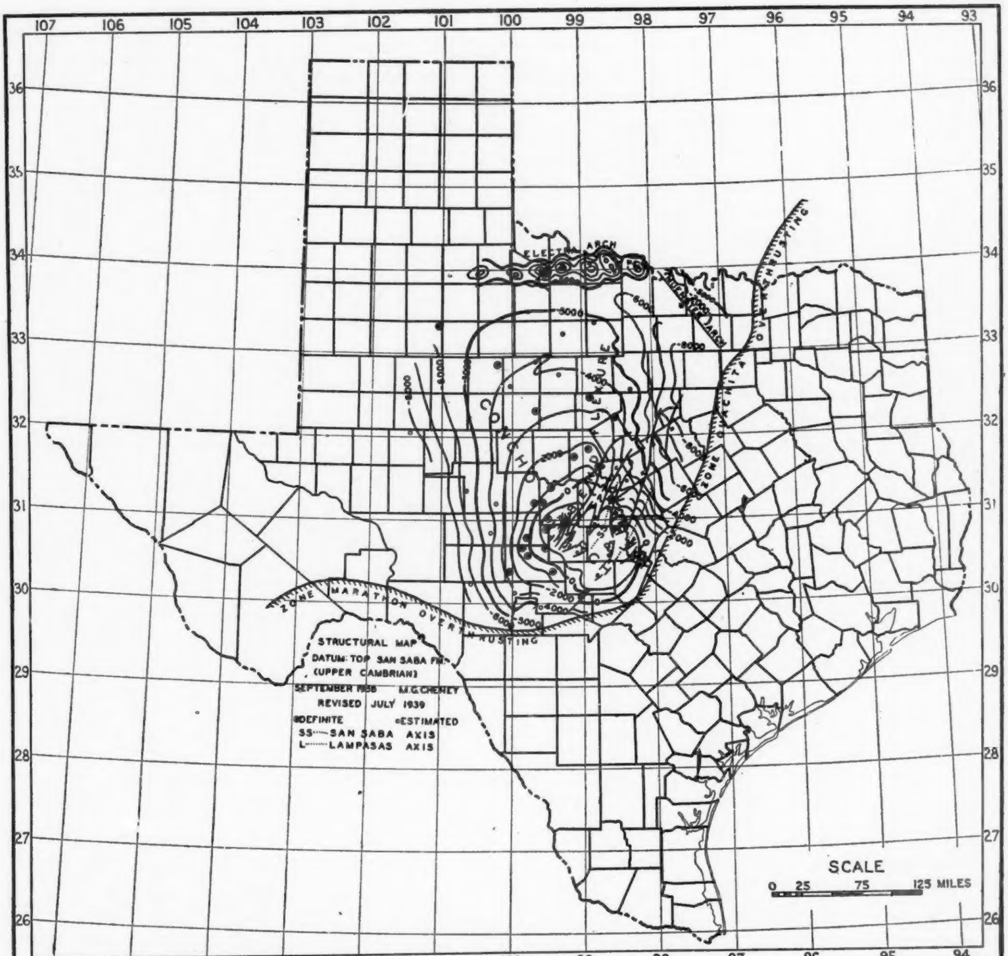


FIG. 8.—Structural map on top of San Saba formation, showing Ouachita-Marathon overthrust, Bend flexure, and Concho, Muenster, and Electra arches. Eastern areas have been greatly elevated and eroded and western areas lowered and deeply buried beneath Permian deposits. Westward tilting since Canyon times has reduced the prominence of the Concho arch and the flexure on its southwest flank but increased the prominence of the regional flexure on its eastern flank.

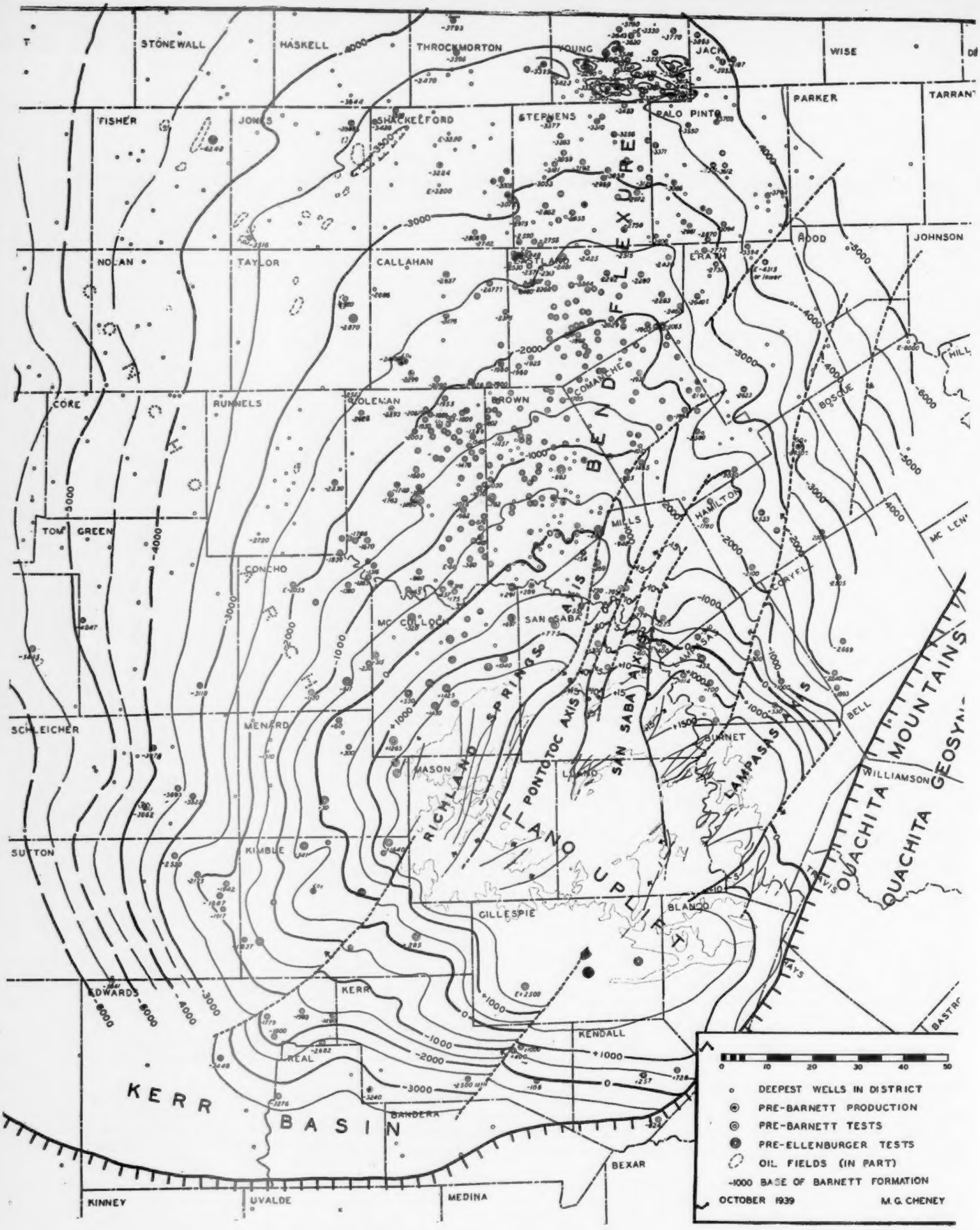


FIG. 9.—Structural map of west-central Texas. Datum: base of Barnett formation. Contour interval: southern Young County, 100 feet; elsewhere, 500 feet; showing Llano uplift, grabens between Richland Springs, Pontotoc, San Saba, and Lampasas axes; also Bend flexure extending northward from Richland Springs axis. Concho arch (Fig. 7) is obscured by westward tilting and truncation of Ellenburger beds. The base of Pennsylvanian beds is used as datum where Barnett beds are absent.

Strawn deposits continue their westward thinning across these features although the rate of thinning is noticeably less in the area west of the Richland Springs axis. The Richland Springs axis forms the southern part of the Bend arch[64] or Bend flexure.[65] These more prominent structural features of west-central Texas are shown in Figure 9. This map also serves to show the location of tests drilled into pre-Barnett formations and localities where pre-Barnett production has been obtained.

A dome evidently developed over an area 20–40 miles across where the Richland Springs axis of post-Smithwick time intersected the Concho arch in eastern Menard County and vicinity. Here uplift and erosion were sufficiently pronounced to permit Canyon deposits to progressively overlap all earlier Carboniferous and the Ordovician beds and come in contact with Cambrian deposits (Fig. 6). On this dome stratigraphic and structural conditions are similar to those on the Central Kansas uplift. Elsewhere along the Concho arch—so far as known to the writer—a thin Strawn and earlier section intervene between Canyon and Ordovician beds.

Graben development of late Lampasas and early Strawn time may have furnished sufficient topographic relief to permit undercutting and landslips. Such a condition aided by channeling may account for the extraordinary boulder bed member of the Haymond group in the Marathon area. This boulder bed member in places is 900 feet thick and contains individual blocks as much as 130 feet long.[66] Graben and landslips followed by intense folding may likewise explain boulder developments elsewhere, as in the Ouachita trough as seen in Johns Valley and other localities.

Evidently progressive uplift was taking place from late Lampasas to early Strawn times inclusive in foreland areas such as the Concho, Muenster, Electra, and Hunton arches. During this time erosion, stream channeling and dumping of material probably took place from both flanks of the relatively narrow, deepening troughs of the Arkansas, McAlester, Ardmore, Strawn, and Kerr basins. During middle and upper Strawn time most of these foreland areas became inundated and covered by deposits derived from rising borderlands, particularly from folds developing in the Ouachita-Marathon troughs

[64] Dorsey Hager, "Geology of the Oil Fields of North-Central Texas," *Amer. Inst. Min. Met. Eng. Bull. 138*, pp. 1109–11.

[65] M. G. Cheney, "Stratigraphy and Structural Studies in North-Central Texas," *Univ. Texas Bull. No. 2913* (1929), pp. 10–11.

[66] P. B. King, "Geology of the Marathon Region, Texas," *U. S. Geol. Survey Prof. Paper 187* (1937), pp. 64–73.

as demonstrated by distinctive chert conglomeratic material in the Des Moines, Strawn, Gaptank, and subsequent deposits.

POST-CANYON: OUACHITA-MARATHON-ARBUCKLE OROGENY

The shallow-water deposits of upper Canyon age have been tilted from their original, approximately horizontal position to a westward-dipping homocline as shown by the lighter lines in Figure 7. Although in most of this region the tilting has been less than one degree from horizontal, it is apparent as a result that eastern areas became elevated three miles or more above the lower parts of the Permian basin of West Texas, which subsided sufficiently to receive sediments nearly 2 miles thick. Since Mesozoic time erosion has not penetrated more than 300 feet below the Comanche beds whereas between Lampasas and Comanche time erosion evidently removed a wedge of Canyon and older beds increasing eastward to a thickness of more than 5,000 feet. In the southeast portion of the Concho arch where these beds were relatively thin the elevated pre-Strawn beds became exposed and extensively eroded over a considerable area, now known as the Llano uplift.

That the Ouachita trough and subsequent orogeny extended southward from southeast Oklahoma into Texas is evident not only by the eastward elevation of Pennsylvanian beds but by much other evidence, such as the presence of vast quantities of detrital Ouachita-facies chert conglomerates in the Strawn, Canyon, and Cisco deposits, and the metamorphosed Jackfork and older beds[67] found beneath the Comanche overlap in wells along a sharply defined zone in trend with exposed Ouachita and Marathon overthrusting. The geologic history of the Ouachita-Marathon geosyncline and subsequent mountain building is so similar to the extensive Appalachian geosyncline and orogeny that a close relationship of these features at least during Pennsylvanian time can scarcely be doubted. Late Pennsylvanian orogeny is most evident in the Marathon area. Similarities cease in Permian time when the Appalachian and Ouachita Mountain areas were rising and the Marathon Mountain area subsiding extensively beneath thick Permian deposits.

Meantime, marine deposits of Canyon age and older were becoming highly tilted on the flanks of the Arbuckle Mountains, progressive uplift during Cisco time being sufficient to permit erosion to remove a sedimentary mantle probably three miles thick and distribute large quantities of granitic material in beds of Wolfcamp age

[67] E. H. Sellards, "Rocks Underlying Cretaceous in Balcones Fault Zone of Central Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15 (1931), pp. 819–27.

over wide areas. The north-central Texas area was affected to some extent by this Arbuckle orogeny as shown by thinning over the northwest trending Electra arch (Fig. 2). Orogenic movements between Canyon and Cisco time also reveal Ouachita influence as indicated by southeastward thinning of lower Cisco beds, in contrast to westward thinning of upper Canyon, as may be observed in southeast well profiles extending into northern Jack and southern Brown counties.

Extensive growth of the Reagan uplift must have occurred somewhat before both middle Strawn and Wolfcamp time as shown by the stratigraphic record (Fig. 4).

The very extensive subsidence of the western part of the Mid-Continent region during Permian time is well known. This movement led to the burial beneath thick sediments of the Amarillo Mountains, Reagan and Pecos[68] uplifts, and the overthrust Marathon Mountains, all of which had been extensively folded and uplifted during late Pennsylvanian time. In going toward present eastern margins from the deeper parts of this Permian basin there are evidences of intermittent uplift such as deposition of enormous quantities of detrital material, regional thinning of beds, transition to more clastic facies, and widespread loss of section below the coarse San Angelo and Whitehorse beds. These are overlain by thick evaporites in the central basin areas. Progressive regional tilting (toward centers of thickest Permian deposition) of all pre-Permian beds and structural features, such as the Concho arch, must have occurred during Permian time, initiated apparently in early Cisco time and probably augmented during the Triassic. Greater westward tilting in west-central Texas than in the northern Mid-Continent area is doubtless due to nearness to the Ouachita uplift on the east and greater subsidence of Permian basin on the west.

In view of the extreme degree of orogeny occurring during late Pennsylvanian time in the Wichita (Arbuckle Mountains included) and Ouachita-Marathon mountain systems, it is reasonable that some adjustments must have followed during Wolfcamp and Leonard time. The unconformities between these series in the Glass Mountains, and the renewed movement of the Potter County fault in the Amarillo region cutting Leonard but not overlying beds,[69] give evi-

[68] The term Pecos uplift is used for the highly folded extensive pre-Permian structural features which underlie the well known Central Basin platform. ("Pecos uplift" has hitherto been considered synonymous with "Central Basin platform."—Editorial note.)

[69] Victor Cotner and H. E. Crum, "Geology and Occurrence of Natural Gas in Amarillo District, Texas," *Geology of Natural Gas* (Amer. Assoc. Petrol. Geol., 1935), pp. 388, 393.

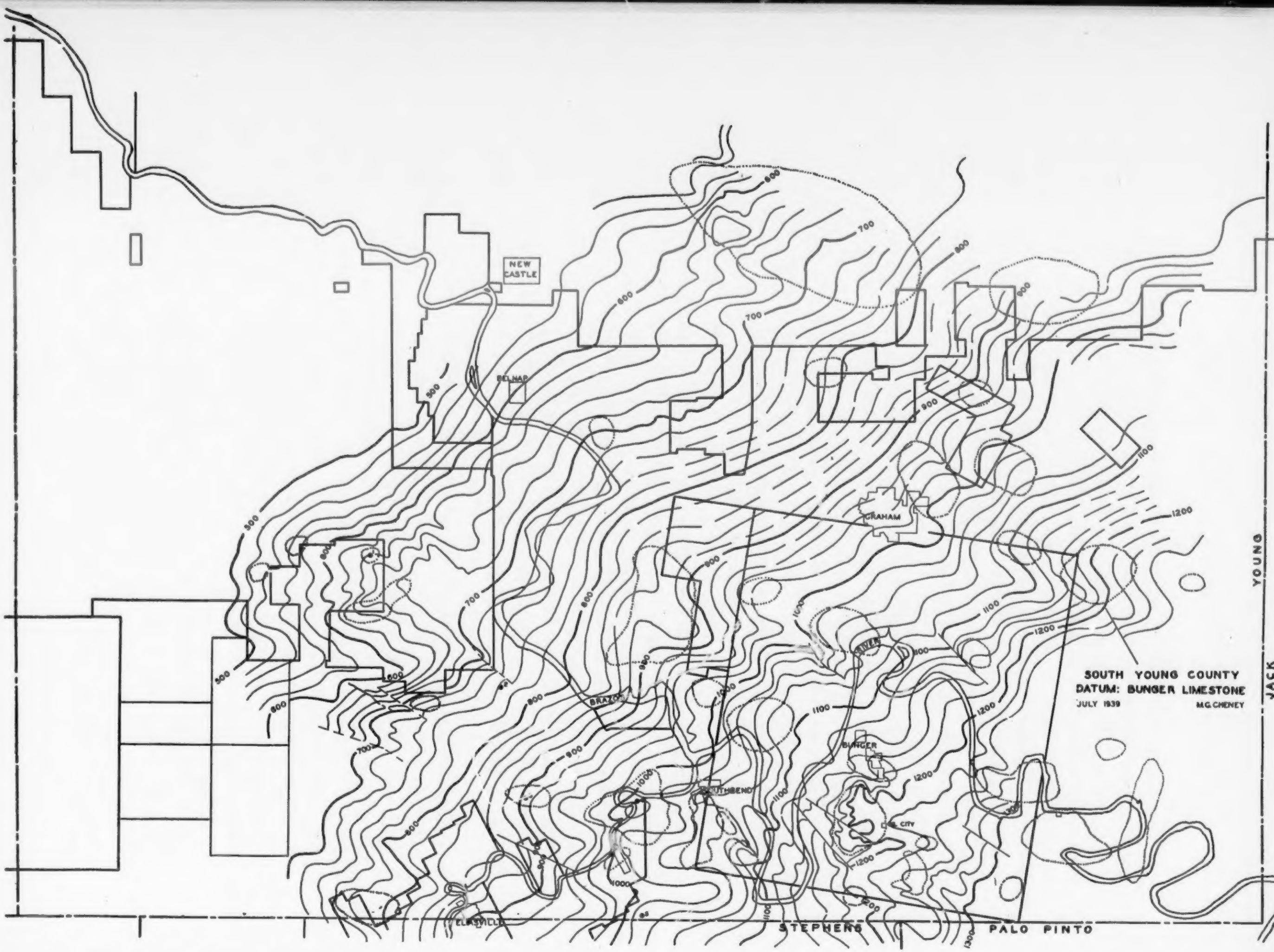


FIG. 10.—Structural map of southern Young County. Datum: Bunger limestone, Cisco series. Contour interval: 20 feet; derived from surface and subsurface structural mapping by the author, supplemented by surface structural mapping by Ben H. Rankin in western part and E. C. Adams and H. S. McLaughlin in eastern part. Producing areas outlined by dotted lines. Wells 1–5 of Figure 5 are located in southwest quarter of this map.

dence of some Permian structural activity. Faults and local folds in Leonard beds are much more strongly developed than in Comanche strata in north-central Texas. It appears probable that considerable folding was developing incident to extensive subsidence in West Texas during post-Leonard Permian time.

That the Concho arch region has gained added structural prominence since Permian time is shown roughly by the present position of the pre-Comanche peneplain.[70] Regional studies by Cartwright[71] permit closer analysis of post-Permian structural changes.

LOCAL FOLDING

The stratigraphic record reveals a progressive but intermittent development from pre-Lampasas to post-Leonard time of several trends of local folding, some of which extend more or less continuously across this region nearly east and west and others northeast and southwest. Trends, as well as intensity of folding and faulting of pre-Barnett beds, over much of this region are shown by Figure 9. This map is contoured in more detail in Young County to permit comparison with folding and faulting affecting lower Cisco beds as shown in Figure 10. Figure 10 also serves to present a detailed study of local folding fairly typical of this region.

Origin, Migration, and Accumulation of Oil

West-central Texas offers many interesting studies bearing on problems of oil source beds and oil migration and accumulation. Thin productive zones are found between thick barren sections over considerable areas; for example, the Gose (or Swastika) sand of the upper Graham group. Some of the smaller sand bodies of the Gose "pay" have given sufficiently high oil yield per acre-foot of sand to show that their pore space was filled with oil (allowing for the ordinary gas content and molecular water film around the sand grains). It is unreasonable to believe that these sand lenses were filled with oil at the time of deposition; hence it follows that the oil must be migratory, in all probability having come from the surrounding brown and dark-colored shales, which are associated with this Gose "pay" through a large area. These shales appear to have had higher organic content than other shales associated with the barren sandstone zones above and below. This appears to give definite evidence that the oil of the

[70] M. G. Cheney, "History of the Carboniferous Sediments of the Mid-Continent Oil Field," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12 (1929), Fig. 8, p. 584.

[71] Lon D. Cartwright, "Regional Structure of Cretaceous on Edwards Plateau of Southwest Texas," *ibid.*, Vol. 16 (1932), pp. 691–700.

Gose "pay" came from the adjacent and surrounding dark shales and that the latter served as source beds.

Barnett and Pennsylvanian shales of similar appearance overlying weathered and fractured Ellenburger beds are considered source beds from which oil may have migrated into these noncarbonaceous truncated reservoirs. Important accumulations of this nature are to be most expected where considerable local uplift existed as in the Big Lake field (Fig. 4) and in folds along prominent arches where truncation permitted the lower, more porous Ellenburger members to be overlapped by source beds in extensive areas thousands of feet above the position of these source beds in the flanking basins. Of course subsequent uplift and truncation of overlying beds might cause the loss of such accumulations. Also later tilting may cause readjustments of fluid levels within structural or stratigraphic traps.

As previously mentioned, westward tilting has rendered the Concho arch obscure but brought prominence to the Bend flexure, when mapped as in Figure 9 with datum horizon contoured in reference to the present sea level. It is believed by the writer that studies of the early structural conditions as revealed by thickness maps (Fig. 7) and cross sections with stratigraphic (Figs. 2 and 4) rather than sea-level base lines need to be emphasized in the study of oil migration and accumulation.

Sedimentary wedges must play a very important rôle in concentrating updip fluid movements from the thick shaly facies of the basin or geosyncline toward thinner, more sandy facies which are commonly found near areas of uplift and erosion, or toward more calcareous deposits of foreland areas distant from sources of clastic material. Such wedges, of course, also serve to supply differential pressure to force movement of fluids in underlying sediments toward areas of less overburden. Thus, in the area east of the Bend flexure, the 200 feet per mile of thickening between Canyon and Lampasas beds must have created differential pressures of about 200 pounds per square inch per mile, forcing movement of fluids in underlying beds along any porous horizon from the basin area toward the Bend flexure and the Concho arch. Such movement would be concentrated along local trends of thinning which in turn would serve to develop and maintain favorable porosity and reservoir conditions in sandstones and limestone beds along such trends. Local closed folds developed along these trends while such compaction and migration of fluids were proceeding would be in favorable position to trap the oil which was being carried along mainly by hydraulic movement. Since these fluid migrations must be exceedingly slow and the oil movement somewhat impeded

by its early high density and high viscosity, there would naturally be by-passing of the water around the oil and gas accumulating in the higher parts of the local folds. Even slight differential pressures seem adequate to control these fluid movements which were no doubt exceedingly slow under natural conditions. Differential pressures of 5.4 and 2 pounds per square inch per mile appear sufficient to maintain horizontal migration of oil and water, respectively, at the prevailing rate of 0.15 mile per year through the less permeable members of the Woodbine reservoir in the East Texas field[72] under present conditions.

Successive deposits of water-filled clays whether or not affected by base exchange are thought to furnish numerous effective barriers to upward escape of most of the water and oil being expelled from the compacting sediments; hence, lateral movement of most of the water and oil through some accessible more permeable bed seems assured. Doubtless the more permeable continuous reservoir beds afford the main avenues of migration. Because most crude oils in the early stages of their evolution are heavy and viscous,[73] no doubt it is difficult for any oil that has coalesced into sizable globules to move through beds having only subcapillary openings. The lateral extent of favorable reservoir conditions, the amount of oil available from associated source beds, and the size and effectiveness of structural or stratigraphic traps must be important factors in determining the amount of oil in a given oil pool or oil field.

Relatively early origin and migration of oil seem demonstrated; for folds of early origin (characterized by local thinning of beds) are generally oil-bearing in contrast to those formed late (without local thinning) which are generally barren, presumably because the main migration of oil had ceased before these late structures were formed. Physical reasons supporting this conclusion were given in previous discussion of this subject.[74] This general principle that compacting masses of sedimentary mineral matter will overcome hydrostatic pressure and cause expulsion and lateral updip migration of fluids from sedimentary basins seems to have been first proposed by King[75] in his studies of ground-water movement.

[72] M. G. Cheney, "Economic Spacing of Oil Wells," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19 (1935), p. 895.

[73] D. C. Barton, "Natural History of the Gulf Coast Crude Oil," *Problems of Petroleum Geology* (Amer. Assoc. Petrol. Geol., 1934), pp. 109–55.

[74] M. G. Cheney, "History of Carboniferous Sediments of the Mid-Continent Oil Field," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13 (1929), pp. 558–59.

[75] F. H. King, "Movements of Ground Water," *U. S. Geol. Survey 19th Ann. Rept.*, Pt. 2 (1899), pp. 79–80.

In this process the migrating water must necessarily carry along lighter fluids and dissolved mineral matter. The name "*compaction-hydraulic theory*" is proposed for this possible explanation of the migration of oil and gas (or dissolved mineral matter) from their source toward the margins of sedimentary basins or geosynclines, such movement being mainly induced by the expulsion of fluids (and mineral solutions) from compacting sediments during periods of increasing pressures due to added overburden or diastrophism, and occurring mainly updip through the more permeable and more continuous strata. This differs from the hydraulic theory of Munn[76] to the extent that it postulates the main controlling movement of fluids (except in reservoirs having intake greatly elevated above sea level) as occurring updip instead of downdip; the time of movement being largely restricted to the early periods when porosity was being reduced actively by sedimentary loading or compressive diastrophic forces instead of later when erosion and unloading progressively reduce pressures; and the source of the migrating water being not meteoric but from the compacting sediments of the basin or geosynclinal areas.

Associated gas and buoyancy of the oil itself may aid lateral movement in the reservoir to some degree, but, when tested quantitatively under theoretically natural conditions, these forces are very minor in comparison to differential pressures varying from 20 to 200 pounds per square inch per mile supplied by wedge-shaped deposits of most sedimentary basins.

Water expelled late in the process of compaction no doubt carries a higher concentration of dissolved salts due to longer intimate association with the finer-grained sediments. This water evidently displaces the original sea water from reservoirs where lack of lower outlet prevents circulation of meteoric water. Likewise some of these updip, migrating waters may bring along much siliceous material to be deposited in areas and zones of cooling, evaporation, or precipitation. This may explain the abundant chert and druse deposits found in some members of the Ellenburger, Chappel, and Marble Falls limestones in north-central Texas and in the Ordovician and Boone limestones of the Ozark region. In both areas large volumes of silica may have been dissolved by warm waters associated with thick chert deposits of Ordovician and Devonian or Mississippian age within the Ouachita trough. An exhaustive study of the origin and

[76] M. J. Munn, "The Anticlinal and Hydraulic Theories of Oil and Gas Accumulation," *Econ. Geol.*, Vol. IV (1909), pp. 509–29.

deposition of Boone chert has been made by Giles,[77] who concluded, among other things, that the chert occurs "as a replacement of the limestone," that "the greater part of the silicification was accomplished before Chester time and preceded the lead-zinc mineralization." Various theories of local source above, within, or below the Boone limestone were reviewed and rejected. The relatively early development of this silicification, the vast quantities of silica and subsequent deposition of heavier mineral matter seem to support a possible lateral updip migration of these solutions from the large near-by geosynclines in accordance with the "compaction-hydraulic theory" as previously discussed.

In north-central Texas, it is difficult to believe that large volumes of migrating fluids passed through the more or less disconnected reservoirs of the region after loading and compaction ceased near the end of Permian time. The thickness of later deposits has not equalled the erosion losses in this region during pre-Comanche time. Most of the reservoirs have no lower outlet to permit circulation by continued admittance of meteoric waters.

Major and minor structural features must have controlled to some degree both the distribution of clastic material brought to the shallow seas of this region during repeated inundations and the development of thick limestone masses seen in the Smithwick group and Strawn and Canyon series.

Many of the sandstone members appear to be local, but the deposition of others seems to have been widespread and controlled to some extent by the major structural features. The Cross Cut, Morris, Fry, and Gardner "sands" of Brown and Coleman counties show southern margins with the trend of the sand body somewhat paralleling the Concho arch. Southeast margins and trends paralleling the Ouachita Mountains are also noted in some of the sand deposits of Strawn, Canyon, and Cisco age. These southwest margins, and subsequently the southeast margins, appear to have served as stratigraphic traps, with oil accumulation now concentrated in local folds near these margins or in the southeast part, that is updip margin, of these reservoirs.

The present permeability of these "pay sands" is known to range from 100 to 850 millidarcys and porosities up to 18.5 per cent or more, averaging about 250 millidarcys and 17 per cent porosity as judged by relatively few core-sample determinations.

The several hundred million barrels of oil accumulated in the

[77] Albert W. Giles, "Boone Chert," *Bull. Geol. Soc. America*, Vol. 46 (December, 1935), pp. 1815–78.

KMA field of southwest Wichita County is no doubt the result of the coincidence of particularly favorable conditions, such as of updip termination of an extensive sedimentary wedge of Strawn beds which included several reservoir members. The main accumulation has taken place where pronounced local folding intersected one of the more prominent *en échelon*, southeast-trending elements of the Electra arch.

More or less local limestone masses developed in the Smithwick group in the Bend flexure region as heretofore described. These have played some part in localizing oil accumulation, for in some areas the oil seems to be in the highest part of the limestone body even though this may not be the highest area structurally.

In west-central Texas several thick localized limestone masses, chiefly with nearly north-south trend, are found in the Canyon beds of western Coleman, eastern Shackelford, eastern Baylor, southern Haskell, and central Taylor counties. A limestone mass extends east and west over much of the Electra arch. This is chiefly of Canyon age. Most of these masses contain some porous zones with sulphur or salt water, oil, and gas commonly present. Certain limestone members have excellent to fair porosity where they occur on prominent structures as in Ivy, Avoca, Noodle Creek, and northeast Fisher County oil fields.

It seems obvious that north-central Texas deserves the continued study of geologists because of the many unsolved problems of stratigraphy and structure. The undeveloped economic natural resources are no doubt of considerable magnitude.

ACKNOWLEDGMENT

It will be recognized that many of the data contained in this paper are derived from studies made by other geologists to whom the writer is much indebted and most grateful for the assistance given. This paper was presented in preliminary form before the annual meeting of the Association at Oklahoma City in 1932. Sidney L. Harris collaborated in this early work. During the past 18 months Miss Louise Jordan has aided very materially with special work on insoluble residues and other laboratory studies.

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VOL. 24, NO. 1 (JANUARY, 1940), PP. 119-133, 5 FIGS.

SAND HILLS AREA, CRANE COUNTY, TEXAS[1]

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ABSTRACT

The Sand Hills area of west-central Crane County includes the Tubb and McKnight pools, in which production is obtained from Permian dolomite. In a third small area on the northwest side of the Tubb pool, five wells have encountered flush production of high-gravity oil near the top of the Lower Ordovician dolomite, and two small wells are producing from a sandstone member of the Middle Ordovician.

Lower Permian dolomite lies unconformably on the eroded surface of a seemingly complex structural system, which involves Lower and Middle Ordovician sediments. Intermediate beds of probably Upper Ordovician, Silurian, and Devonian ages, respectively, appear in a test which was drilled approximately 8 miles southeast of the Ordovician producing area.

STRATIGRAPHY

An understanding of the stratigraphic positions of the Permian and Ordovician producing sections may be afforded by a description of the formations (Fig. 2) penetrated by tests.

LOWER ORDOVICIAN (ELLENBURGER)

All beds of Lower Ordovician dolomite in this area are placed in the Ellenburger group. The writer believes, however, that beds of younger age are present here than are exposed in the Central-Mineral region where the Ellenburger[3] was originally described. It is also recognized that some of the lower beds here included in the Lower Ordovician may belong to the Upper Cambrian.

A thickness of 1,312 feet of Ellenburger dolomite was penetrated by Loffland Brothers' Tubb No. 3. At least some portion of the uppermost beds was removed by erosion, the Permian resting directly on its eroded surface. All other tests penetrated only 10–200 feet of beds below the top of the Ellenburger.

The Ellenburger group consists of gray and brown, massive, dense dolomite, being predominantly fine crystalline in the upper 200 feet and containing beds of color-banded and mottled dolomite. Below these upper beds, the main body of the Ellenburger is gray and brown, medium to coarse crystalline dolomite. Nodular, gray chert occurs in small amounts. Partially rounded and frosted sand grains appear here and there in thin lenses and as floating grains in a dolomite

[1] Read before the Association at El Paso, September 29, 1938. Manuscript received, August 26, 1939.

[2] Gulf Oil Corporation.

[3] Sidney Paige, "Description of the Llano and Burnet Quadrangles," *U. S. Geol. Survey Folio 183* (1912), p. 7.

FIG. 1.—Index map of Sand Hills area, showing location of pools and line of cross section.

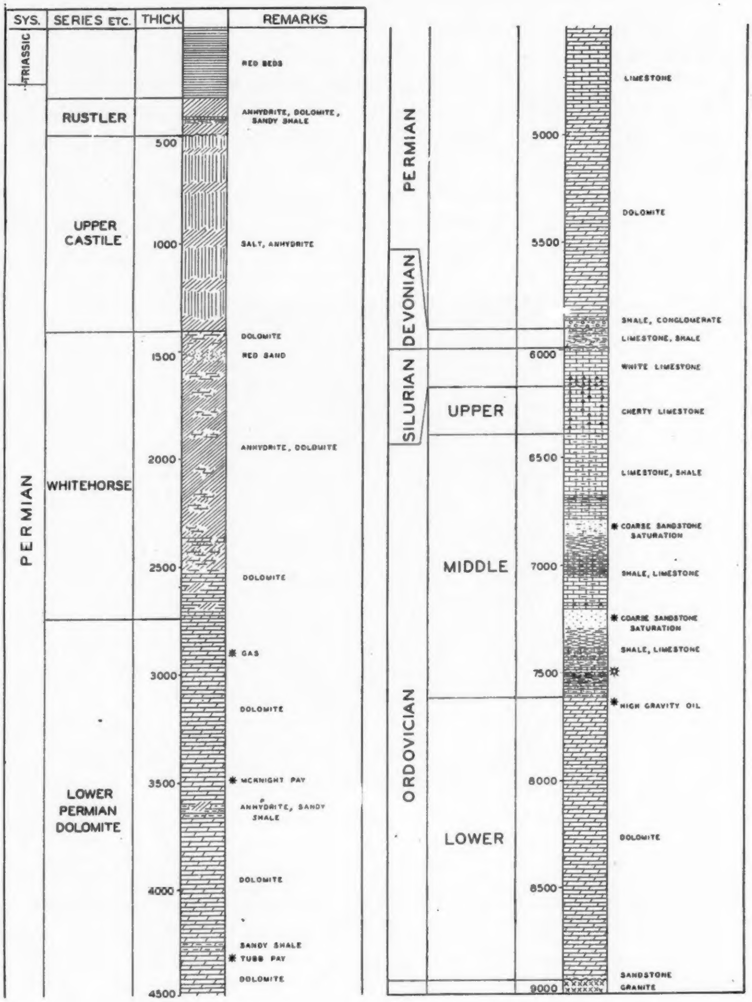

FIG. 2.—Generalized columnar section of formations penetrated in Sand Hills area.

matrix in the upper 200 feet. The lower 500 feet of dolomite in the Ellenburger section of the Loffland Brothers test contains scattered sand grains, and the basal 15 feet consists of dolomitic sandstone which lies directly on a granitic mass.

Fossils are notably rare and poorly preserved in the dolomite. One trilobite pygidium was found 24 feet from the top in the Gulf's Tubb No. 16. A few gastropods have been found in the upper 200 feet.

MIDDLE ORDOVICIAN (SIMPSON)

The base of the Middle Ordovician (Simpson) lies on, and in sharp lithologic contrast to, the massive Lower Ordovician (Ellenburger)

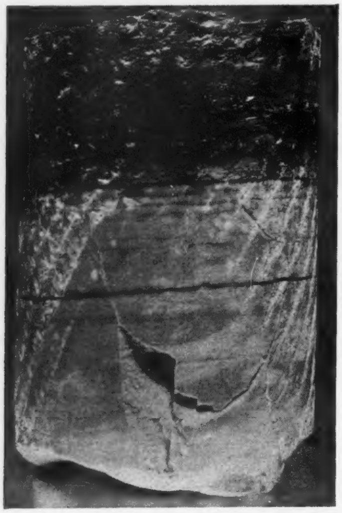

FIG. 3.—Core from Gulf's Waddell No. 1, showing contact of Ellenburger and Simpson.

dolomite. The actual plane of contact (Fig. 3) has been recovered in cores from several of the tests. The stratigraphic relations between the Ellenburger and Simpson remain to be determined, but we have not yet found any evidence of an erosional unconformity at that horizon. The lithologic character of the lower Simpson beds, which makes them readily traceable between the several tests, shows no evidence of overlap on the Ellenburger surface, and no reworked Ellenburger dolomite has been found incorporated in the basal Simpson beds. Cores indicate that the bedding planes below and above the contact are essentially parallel. The lithology of the uppermost beds of the Ellenburger shows that the Simpson is everywhere in contact

with the same bed in the Sand Hills area. Since only a meager fauna of gastropods has been found in subsurface, lithology and insoluble residues will have to be relied upon to give clues concerning the regional relationship between these two units.

The thickest section of Middle Ordovician yet known in the general area was penetrated by the Magnolia's McKee No. 1, located 13 miles south of the Waddell discovery well. Several hundred feet of cores from this well give a good picture of lithology and sequence of beds. The eroded surface of the Ordovician was encountered in this test at a depth of 4,775 feet and the base of the Middle Ordovician at a depth of 6,102 feet, thus showing a total of 1,327 feet. The upper 110 feet of this section is questionably considered Upper Ordovician.

No attempt will be made at this time to present a detailed classification and correlation of the Middle Ordovician, but faunal evidence shows that a fairly complete equivalent to the Simpson of Oklahoma is present in the McKee test. It is the general equivalent of the Woods Hollow and Fort Pena formations of the Marathon uplift, Brewster County, Texas. Available faunal identifications are inadequate, at this time, for delimitation of the several stratigraphic units, but the combined faunal and lithologic features have made it possible to trace certain beds between tests.

In the following description, the Middle Ordovician (Simpson) falls into a sequence of zones, which may be called, from bottom to top, "A," "B," "C," and "D" for convenience, until such time as fossil evidence can be utilized. This four-fold subdivision may or may not coincide with a faunal subdivision. The lithologic descriptions are supplemented by the detailed graphic section shown in Figure 4. The thicknesses which accompany the descriptions of the several beds were taken from a record of the McKee test, since that test is the only one which has penetrated the entire Simpson.

Thickness in Feet	
	ZONE "D"
240	BED NO. 15. Predominantly gray and brownish gray, fine to coarse crystalline, fossiliferous limestone. Section is massive, with green shale intermixed and occasional thin layers interbedded with limestone. A few beds have a small amount of fine sand. Brachiopods and ostracods common
15	BED NO. 14. Reddish and green, fine sandy shale and gray limestone interbedded. This reddish stained bed is recognized in both Barnsley and McKee tests
105	BED NO. 13. Thin beds of green shale, gray, fine to medium crystalline limestone, and white and greenish, calcareous and shaly, fine to medium-grained sandstone, all being interbedded. Ostracods and brachiopods common
58	BED NO. 12. Fine to coarse-grained sandstone, cemented with calcareous and bright green shaly material, and interbedded with grayish green sandy shale and limestone. Sandstone is finely conglomeratic, and contains common black chert-like granules. Middle 8 feet of sandstone is porous and saturated with oil in the McKee test

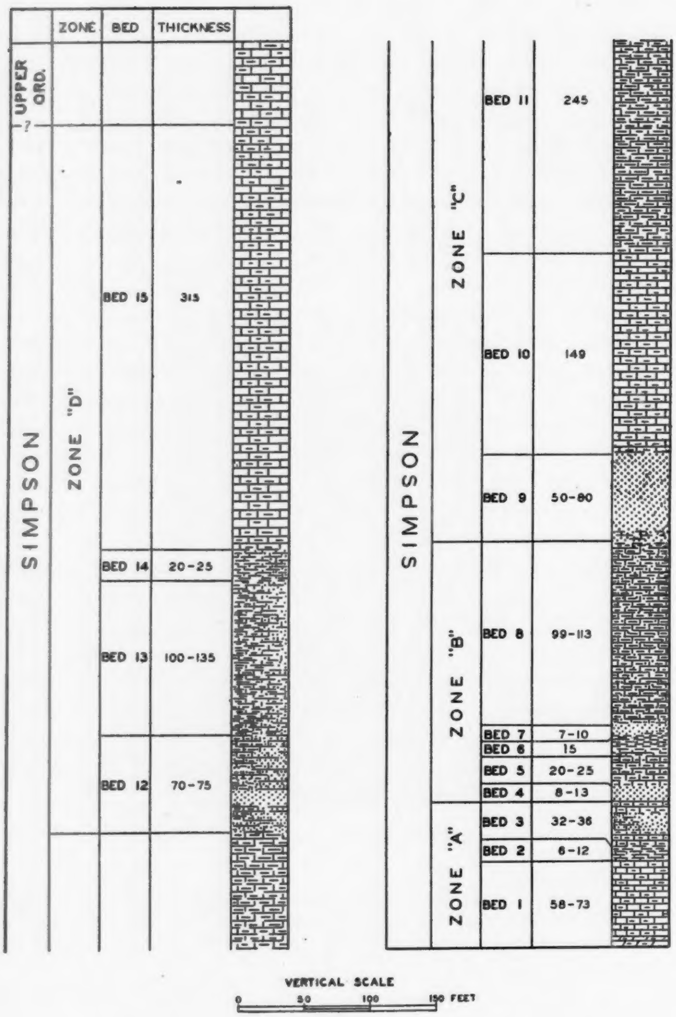

FIG. 4.—Graphic section of Middle Ordovician (Simpson) of Sand Hills area.

ZONE "C"

245 BED NO. 11. Predominantly grayish green shale (50 to 60 per cent), irregularly interbedded with very fossiliferous, thin-bedded limestone. Small amount of silt intermixed. Note absence of large sand grains. *Rafinesquina* sp. and *Strophomena* sp., and small, plicated brachiopods common. Trilobites rare. Large pelecypods (*Modiolopsis sp.*) abundant in several beds of a 57-foot section, beginning 140 feet below top

151 BED NO. 10. Predominantly gray and white, fine to coarse crystalline, very fossiliferous limestone (80 to 85 per cent of section). Here and there coquina-like beds. Green shale intermixed with limestone and in thin beds and laminae. Silt commonly intermixed with both limestone and shale. Note absence of coarse, rounded, and frosted sand grains, except in lower 15 feet. Cherty in lower 12 feet of McKee section. *Strophomena* sp. and *Rafinesquina* sp., and small, plicated brachiopods very common. Small, branching bryozoa and large bryozoa common. Crinoid stems, cystoid plates and stems common. Trilobites and graptolites rare. Small algal concretions common

50 BED NO. 9. Predominantly white, coarse-grained, calcareous sandstone. Some beds of shale and calcareous siltstone. Most of section porous. Sand grains secondarily enlarged in porous beds. This is producing sandstone of Gulf's Waddell Nos. 1 and 2

ZONE "B"

168 BED NO. 8. Average of 55 per cent green shale, 40 per cent limestone and 5 per cent sand. Green shale irregularly interbedded with fine to very coarse crystalline, very fossiliferous limestone, which has conglomeratic appearance due to reworked limestone pebbles. Coarse sand intermixed with both shale and limestone, and as thin beds of shaly sandstone in upper 20 feet of bed. Abundant ostracods, brachiopods, bryozoans, and crinoid stems; and common conodonts, and gastropods. Rare graptolites and trilobites

13 BED NO. 7. White, coarse-grained, calcareous sandstone with bright green shale intermixed (3-7 feet). The sandstone is underlain by 2 feet of green and purple shale, and that by three feet of green shale laminated with white, calcareous sand

23 BED NO. 6. Predominantly grayish green, massive shale with scattered nodules of dense and coarse crystalline, fossiliferous limestone in lower 7 feet

22 BED NO. 5. Predominantly thin-bedded and nodular, coarse crystalline, very fossiliferous, coarse sandy limestone, containing reworked tabular pebbles of limestone. Green shale is irregularly interbedded with the limestone

8 BED NO. 4. Brownish, coarse-grained, calcareous, non-porous sandstone. Brown and white mottled appearance due to brown staining. Common replacements of brachiopods, gastropods, *et cetera*

ZONE "A"

57 BED NO. 3. Gray, very fossiliferous, bedded and nodular limestone, interbedded with greenish shale. An 11- to 20-foot bed of very calcareous, coarse-grained sandstone, beginning at a distance of 8 feet from top

14 BED NO. 2. Greenish gray shale, interbedded with dense limestone. Scattered sand grains. Three feet of green shale at top with characteristic graptolites (*Didymograptus* sp.), ostracods, brachiopods, and conodonts

48 BED NO. 1. Gray, dense, slightly shaly and sandy limestone. Shaly streaks, variable texture, and fossil fragments give streaked and mottled appearance. Locally dolomitized, with resultant solution porosity which produces oil in Gulf's Waddell No. 4. Lies on Ellenburger dolomite

UPPER ORDOVICIAN

The Barnsley test encountered 220 feet of predominantly light gray and smoky chert, interbedded with light brownish limestone, which contains fragments of brachiopods and ostracods in lower 100 feet. This section lies directly on the Simpson and probably belongs

to the Upper Ordovician.[4] The McKee test encountered 110 feet of gray and greenish limestone, being slightly shaly in certain beds, and containing fragments of brachiopods and bryozoans which may possibly belong to the Upper Ordovician rather than uppermost Simpson.

SILURIAN

In the Barnsley test, the Upper Ordovician is overlain by 178 feet of white, crinoidal limestone, a few beds being slightly pinkish. Glauconite is rare in the central part of the section. The lower 50 feet is siliceous and oölitic. The lithologic similarity of this section to the 195 feet ascribed to the Silurian in the Gulf's McElroy No. 103 makes that correlation probable.

DEVONIAN

Above the Silurian of the Barnsley test there is a section of 90 feet of dark gray and bluish gray, arenaceous shale interbedded with dolomite. This is questionably considered Devonian by Upson,[5] its lithologic similarity to the basal Devonian of the McElroy test being used as a basis for correlation.

PERMIAN

Permian sediments lie unconformably on the eroded surface of the Middle and Lower Ordovician in the Sand Hills proper. On the east flank of the pre-Permian uplift, intervening beds of Upper Ordovician, Silurian, and Devonian ages appear in the Barnsley test. The lowermost 70 feet of Permian in this test consists of reddish, shaly, sandy conglomerate, which appears to be older than the base of the Permian in the Sand Hills.

The basal Permian in the Sand Hills is characterized by thin beds of carbonaceous shale and reworked material from the underlying erosional surface incorporated in the lower 20–30 feet. The lower main body of the Permian section consists of 2,500–3,180 feet of brown and gray dolomite beds. Intercrystalline and nodular anhydrite occur through most of the section. Brown and gray, silty shale, and bedded anhydrite are recognized in wells at a penetration of 800–900 feet into this section. At a distance of approximately 700 feet below the silty shale and anhydrite zone there are persistent beds of fine sand and shale. Beds of gray limestone are present in the lower 1,100–1,200 feet of the lower Permian dolomite.

[4] C. D. Cordry, personal communication, 1939.

[5] M. E. Upson, "Pre-Permian Stratigraphy and Microfauna of the Deep Wells of West Texas," unpublished paper (1937).

Overlying this dolomite is the Whitehorse group,[6] which consists of 1,260–1,370 feet of anhydrite and dolomite, with the Yates sand near the top and predominantly dolomite in the lower 400 feet. The next overlying 825–990 feet of salt and anhydrite is considered Upper Castile. This is overlain by 115–225 feet of anhydrite, dolomite, and sand, which belongs to the Rustler formation. The Rustler is overlain by 250–400 feet of Permian and Triassic red shale and sand.

PRODUCTION OF OIL AND GAS

TUBB POOL

The discovery well of the Tubb pool was drilled in 1930 and 1931 by the Gulf Oil Corporation and Cranfill Brothers on the Tubb tract. The test, which was drilled to a depth of 5,335 feet, encountered several showings of oil and gas, the best occurring from 4,300 to 4,400 feet. In the same years, a Permian test was drilled to a depth of 4,510 feet by the Penn Oil Company on the Tubb tract, which failed to show commercial oil, and a second unsuccessful test was drilled to a depth of 4,457 feet by Cranfill Brothers on the Muir tract.

Since that time, 28 wells have been completed by the Humble Oil and Refining Company, 15 by the Gulf Oil Corporation, 9 by the Aloco Oil Company and the American Liberty Oil Company, one by the Sinclair Prairie Oil Company (Unit), and one by Loffland Brothers. Thus a total of 54 wells are now (August, 1939) producing on the Tubb properties between the average depths of 4,250 and 4,420 feet, or approximately 1,600 feet below the base of the Whitehorse group. The producing section of these wells has therefore been called conveniently the "Tubb pay."

A few other beds of the Permian dolomite section carry small showings of oil and gas in the Tubb pool, but few of these are productive. The Loffland Brothers' Tubb No. 2 encountered a small showing of oil in the "Tubb pay"; however, its main production comes from the 4,650-foot level. Large volumes of gas have been encountered between the depths of 2,650 and 3,100 feet in several wells,

[6] The name *Whitehorse* has been used in this article and its boundaries drawn to conform with the general opinion in order not to further add to the confusion of nomenclature by introducing a different series of names. C. D. Cordry states, "It was an unfortunate choice when the name *Whitehorse* was introduced into the nomenclature of the Permian Basin. Since many of the units recognized in the subsurface of the Permian Basin do not outcrop on the eastern edge, due probably to lenticularity as well as overlap by higher beds, and since these units have definite correlative value, and can be observed on the surface immediately to the west of Carlsbad, New Mexico, it is hoped that when a satisfactory nomenclature has been published on these outcropping units, that the above mentioned (Carlsbad) area may become the standard section of reference for the subsurface in the Permian Basin, especially for that part of the section now rather loosely referred to as 'Whitehorse.'"

the largest being 10 million cubic feet per day in the American Liberty Oil Company's Tubb No. 1 at a depth of 2,700 feet. This test is located one mile southeast of present production in the Tubb pool.

Three other tests of the "Tubb pay" in the area have failed. The Loffland Brothers' Tubb Nos. 1 and 3 encountered small showings of oil but poor conditions of porosity. The Gulf's Waddell No. 3, located one mile north of the Tubb pool, also failed to find production above a depth of 4,800 feet.

The more or less barren conditions of the "Tubb pay" in tests drilled on the north, west, and south sides of the Tubb pool are evidently due to lateral reduction of porosity in spite of favorable structural positions.

The 54 wells of the Tubb pool have a cumulative initial daily potential of 90,521 barrels of oil, or an average of 1,676 barrels per well. The largest producer in the pool is the Gulf's Tubb No. 2, which was rated at 8,400 barrels per day. All wells in the pool are flowing, the average flowing ratio being 1,600 cubic feet of gas to 1 barrel of oil. The gravity of oil in the Tubb pool is approximately 35° A.P.I. at 60°F. Initial reservoir pressures, taken under different conditions, range from 1,600 to 2,100 pounds per square inch. In the Tubb pool proper, several wells have been drilled from 20 to 40 feet below the base of the oil-bearing beds without encountering water.

MCKNIGHT POOL

In 1935, the discovery well of the McKnight pool was drilled by the Gulf Oil Corporation on the McKnight tract to a depth of 3,715 feet, and completed with an initial daily potential of 73 barrels of oil. Since that time, two other small wells have been drilled by the same company ¾ mile northeast of the discovery well. Well No. 2 was drilled to a depth of 5,400 feet with cable tools and plugged back to the "McKnight pay." Well No. 3 was drilled with rotary to test the Ordovician, and after failure in the lower sections, plugged back to the "McKnight pay." A fourth test, located 1 mile northwest of Nos. 2 and 3, was plugged and abandoned after failure in both Permian and Ordovician.

The three oil wells produce from dolomite of the "McKnight pay" section between the depths of 3,450 and 3,750 feet. This producing section is approximately 550 feet below the base of the Whitehorse group and is 900 feet higher, stratigraphically, than the "Tubb pay."

Three producers of the McKnight pool have a cumulative initial daily potential of 203 barrels of oil, or an average of 67 barrels per well. All the wells are pumping, and produce appreciable quantities

of sulphur water with the oil, thus showing a close association of oil and water in the section. The gravity of the oil in the McKnight pool is 31° A.P.I. at 60°F. On January 1, 1939, a total of 10,000 barrels of oil had been removed from the pool.

ORDOVICIAN DEVELOPMENT

The Ordovician development prior to 1938 has been outlined by C. D. Cordry.[7] After the Gulf Oil Corporation had drilled McElroy No. 103 near Crane, Texas, to a depth of 12,786 feet, testing the upper 395 feet of the Ellenburger dolomite, core drilling and geophysical work were done in the Sand Hills area to obtain further information to be used in locating an Ordovician test. The Gulf's Waddell No. 1, the Ordovician discovery well, encountered Simpson sediments in contact with Permian at a depth of 5,875 feet, or approximately 6,000 feet higher, structurally, than equivalent beds in the McElroy test, located 20 miles farther east.

Since that time, nine other Ordovician tests have been drilled by the Gulf Oil Corporation on the Waddell properties, two on the McKnight, and one on the Tubb. Other tests are the Sinclair Prairie's Tubb Nos. 2 and 3 (Unit) and the Loffland Brothers' Tubb No. 3. The Moore Brothers' Barnsley No. 1 is located 9 miles southeast of the discovery well. The Magnolia's McKee No. 1 is located 13 miles south of the discovery well in northern Pecos County. Other tests outside of the Sand Hills area are the Magnolia's Eaton No. 2, located 7 miles southwest of the McKee test, and the Anderson-Prichard's Masterson No. 1, located 11 miles south of the McKee test.

At the present time (August, 1939), five wells on the Gulf's Waddell tract are producing oil from the upper portion of the Ellenburger dolomite. The wells were completed at the following 24-hour rates: No. 4 at 1,800 barrels, No. 5 at 8,179 barrels, No. 7 at 3,656 barrels, No. 9 at 2,678 barrels, and No. 10 at 854 barrels. All these wells are producing from a penetration of 10–55 feet in the Ellenburger, the top of the producing zone coinciding with the Ellenburger-Simpson contact. In well No. 4, solution porosity was developed by secondary dolomitization of the lower 65 feet of limestone in the Simpson (Fig. 4, bed No. 1). This is the only well in the area that showed oil and gas in this particular zone.

The Ellenburger tests appear to produce oil or water principally from open fractures. The formation, being relatively highly folded, is typically fractured, the fractures being open and more common near

[7] C. D. Cordry, "Ordovician Development, Sand Hills Structure, Crane County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21 (1937), pp. 1575–91.

the crest of the structure and tighter and less common on the flanks. A zone of cavernous type of porosity was encountered in the Gulf's Waddell No. 1 at a penetration of 70 feet and in No. 2 at 83 feet.

The oil that is produced from the Ellenburger dolomite has a gravity of 45° A.P.I. at 60°F. The average reservoir pressure is approximately 2,700 pounds per square inch. Water appeared in No. 10 some time after initial production tests were made. The water level therefore seems to be not far below the total depth of this well, which was drilled to 6,027 feet, or to 3,490 feet below sea-level. All other tests encountered the Ellenburger below that level, with the exception of the Loffland Brothers' Tubb No. 3, which found Permian sediments on the eroded surface of the Ellenburger dolomite. Discounting the removal of some of the upper Ellenburger beds, this test is at least 135 feet higher, structurally, than the Gulf's Waddell No. 9, yet the Loffland Brothers' test showed sulphur water near the top of the formation.

Although the Anderson-Prichard's Masterson No. 1 is located several miles south of the Sand Hills area, it is important in this connection. In this test, the Permian rests unconformably on the Ellenburger dolomite, the entire 1,327 feet of Middle and Upper (?) Ordovician of the McKee test and some of the upper Ellenburger having been removed. A penetration of 50 feet below the contact yielded 184 barrels per day of high-gravity oil from porous dolomite. Similarly, the Magnolia's Eaton No. 2, located 7 miles southwest of the McKee test, found Permian resting on eroded Ellenburger, but at a level of 571 feet lower than the same contact in the Masterson test. This test encountered sulphur water in porous dolomite.

The Simpson has shown oil and gas in three different beds, in addition to the occurrence mentioned above in Waddell No. 4. In the Gulf's Waddell Nos. 9 and 10 and Tubb No. 16, and in the Sinclair Prairie's Tubb No. 3 (Unit), porosity was developed in a very calcareous sandstone (Fig. 4, bed No. 3), which is approximately 75 feet above the base of the Simpson. In Waddell Nos. 9 and 10, this sand showed approximately 20 million cubic feet per day of gas and 250 barrels of distillate, whereas, the other tests, being structurally lower, showed water. In all other tests, with the exception of these four, this bed is a non-porous, calcareous sandstone.

The base of the producing sandstone (Fig. 4, bed No. 9) of the Waddell (Ordovician) area occurs at approximately 275 feet above the base of the Simpson. Waddell No. 1 was completed, producing 122 barrels per day of 35°-gravity oil from this zone, and Waddell No. 2, being 125 feet lower, structurally, was completed, producing 25 bar-

rels. Very little gas occurs with the oil, and both wells have to be pumped. This sandstone was present in the Gulf's McKnight No. 4, and the basal beds were present in the Sinclair Prairie's Tubb Nos. 2 and 3 (Unit), but is absent from other tests due to erosion. It showed saturation in the McKee test, but not in commercial quantities. In the Sinclair Prairie's Tubb No. 3 (Unit) it showed a large volume of gas, which is similar to the gas that occurs in the lower "gas sand" of Waddell Nos. 9 and 10. Communication is possible between these sandstone beds along the Ordovician-Permian unconformity, since both are truncated within the immediate vicinity.

A third sandy zone (Fig. 4, bed No. 12), which occurs approximately 800 feet above the base of the Simpson, showed oil and gas in the McKee test, but seemed to be non-porous in the Barnsley test.

STRUCTURE

The accompanying cross section (Fig. 5) shows a relatively small amount of relief on the pre-Permian erosion surface, which locally conforms, in a general way, to the structure based on certain Permian horizons. Cores and other structural control from wells on the Ellenburger-Simpson contact indicate common dips of 8°–15°. There seem to be several local structures, involving folding and possibly faulting, which lie on and are subsidiary to a major pre-Permian uplift. One of these features is indicated in the vicinity of the Gulf's McKnight Nos. 3 and 4. Another is the Waddell feature, which seems to be a northwest-southeast trending fold with a double pitching axis. Bordering this feature on the east, the Sinclair Prairie's Tubb No. 2 (Unit) showed approximately 10° dips in the highest Simpson beds, which increased to a maximum of 60° at the base of the Simpson and then decreased to 10° below. At a distance of one mile east of this feature, the Loffland Brothers' Tubb No. 3 encountered Permian on eroded Ellenburger dolomite. The top of the Ellenburger in this test is at least 371 feet higher than the same point in the Sinclair Prairie test. Both faulting and folding have been offered as explanations for this reversal of structure at the east.

The Cranfill Brothers' Muir No. 1, which is structurally the highest Permian test in the Sand Hills area, did not penetrate the entire Permian section, but an estimate of the level at which the base of the Permian may occur indicates that the Permian structure is possibly a reflection of relatively high structure in pre-Permian sediments as well as a high pre-Permian erosion surface.

The Barnsley test shows intervening beds between the Permian and Middle Ordovician, which are absent in the Sand Hills proper.

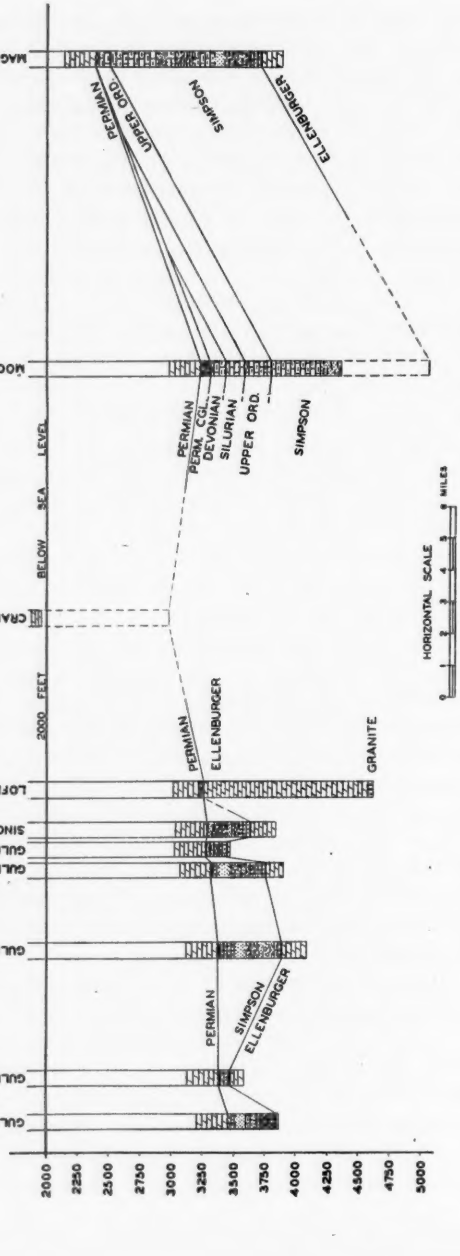

FIG. 5.—Cross section showing structure of pre-Permian sediments in Sand Hills area.

A correlation of the upper Simpson of this test with that of the McKee test may be used as a basis for estimating the level of the Ellenburger-Simpson contact. The Barnsley test thus appears to be 1,300 feet or more down the structural dip on the east side of the pre-Permian uplift.

The 1,327 feet of Middle and Upper Ordovician sediments of the McKee test are cut out in a short distance by Permian truncation as the structure rises to the south toward the Masterson test and to the southwest toward the Eaton test. Located 8 miles still farther southwest of the Masterson test, the Shell-Kirby's University No. 1 found Permian on granite. The steep dips involved in these three tests render it difficult to determine whether they occupy relatively high structural positions on a major, persistent uplift or whether they represent separate features.

An attempt to construct a structural contour map on the Ordovician is not considered advisable at this time. Future development will probably reveal a complex structural system underlying the relatively featureless Permian section.

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STRUCTURAL DEVELOPMENT, YATES AREA, TEXAS[1]

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ABSTRACT

The marked Cretaceous surface structure overlying arched Permian limestones in the Yates area in eastern Pecos County, Texas, was developed by salt solution rather than folding. The solution was active in two stages. In the first, salt was removed from the crest of the dome and the hole left by this solution was filled with clastics. Cretaceous beds were laid down flat over this clastic plug. Post-Cretaceous solution developed a ring syncline around the plug and produced the present surface structure.

INTRODUCTION

The pronounced surface dome near Iraan in eastern Pecos County, Texas, is one of the most easily recognized closed structures in the Permian basin. Since the Yates discovery in 1926, the area has been extensively drilled. An examination of the surface and subsurface data now available shows that the structure of the Permian "lime" and Cretaceous surface beds are markedly different and are related only secondarily.

The stratigraphy and structure of the Yates area have been described in previous papers,[3] but so far no attempt has been made to present a comprehensive picture of the structural development. A series of cross sections is included in this report to reconstruct the geologic history of the area.

ACKNOWLEDGMENTS

The writer is indebted to many geologists who have worked in Yates, but especially to Fred S. Wright, whose early recognition of the significance of salt solution aided greatly in interpreting local stratigraphic problems, and to E. Russell Lloyd, whose encouragement is mainly responsible for the completion of this paper. Data are from the files of the Standard Oil Company of Texas.

STRATIGRAPHY

No deep wells have been drilled in the Yates field and the stratigraphic discussion is, therefore, limited to upper Permian and post-Permian sediments. The deeper wells are bottomed in a crystalline

[1] Manuscript received, August 28, 1939.

[2] Standard Oil Company of Texas.

[3] G. C. Gester and H. J. Hawley, "Yates Field, Pecos County, Texas," *Structure of Typical American Oil Fields*, Vol. 2 (Amer. Assoc. Petrol. Geol., 1929), pp. 480–99.
John Emery Adams, "Origin of Oil and Its Reservoir in Yates Pool, Pecos County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 6 (June, 1930), p. 705.

dolomite that carries a poorly preserved fauna of lower Word or upper Leonard age.[4] These beds are overlain disconformably by upper Permian Whitehorse dolomites and evaporites. The basal Whitehorse limestones are between 125 and 150 feet thick. The overlying or evaporite section is made up of anhydrite interspersed with irregular lenses of sand, shale, and salt, with the Yates sand and Tansill evaporite formations at the top. The thickness of the Whitehorse varies from 560 feet to 1,280 feet along the line of the section, but in the lower parts of the Midland basin measures more than 2,300 feet. The Permian section above the Whitehorse includes the anhydrites, dolomites, salts, and clastics of the Upper Castile, Rustler, and uppermost Dewey Lake groups. One widespread dolomite-anhydrite zone near the base of the Castile, the Cowden anhydrite, is continuous and distinctive enough to be shown on the cross sections as a stratigraphic unit. Members above the Yates are fully developed only on the flanks of the structure.

Above the Permian is a thin succession of Triassic gravels and sands. On the crest of the dome the Triassic is covered by Cretaceous, lagoonal clastics. Elsewhere the oldest Cretaceous is a basement sand, probably of Paluxy age. The sand is overlain by a thick succession of Edwards-Comanche Peak limestones. The Cretaceous limestones are omitted from the cross sections because of the extreme irregularity in topography and because they add little to the structural picture of the area. Several hundred feet of recent fill are present in the valley of the Pecos River.

STRUCTURAL DEVELOPMENT—CROSS SECTIONS

The structural development of the Yates area was initiated in beds older than any so far penetrated on the dome. The oldest break of which we have record is the gap between the Whitehorse dolomites and the underlying Word-Leonard section. This unconformity was caused by pre-Whitehorse erosion and non-deposition over a local topographic "high" and correlates with the basal Whitehorse unconformity recognized in many of the structurally high areas of the Permian basin. The unconformity is not shown on the accompanying sections because it occurs in the lower part of the producing zone and cuttings were not collected from this part of the hole in many of the wells.

The Whitehorse and younger beds include mappable units from which the late Permian and post-Permian structural history can be reconstructed.

[4] John W. Skinner, personal communication.

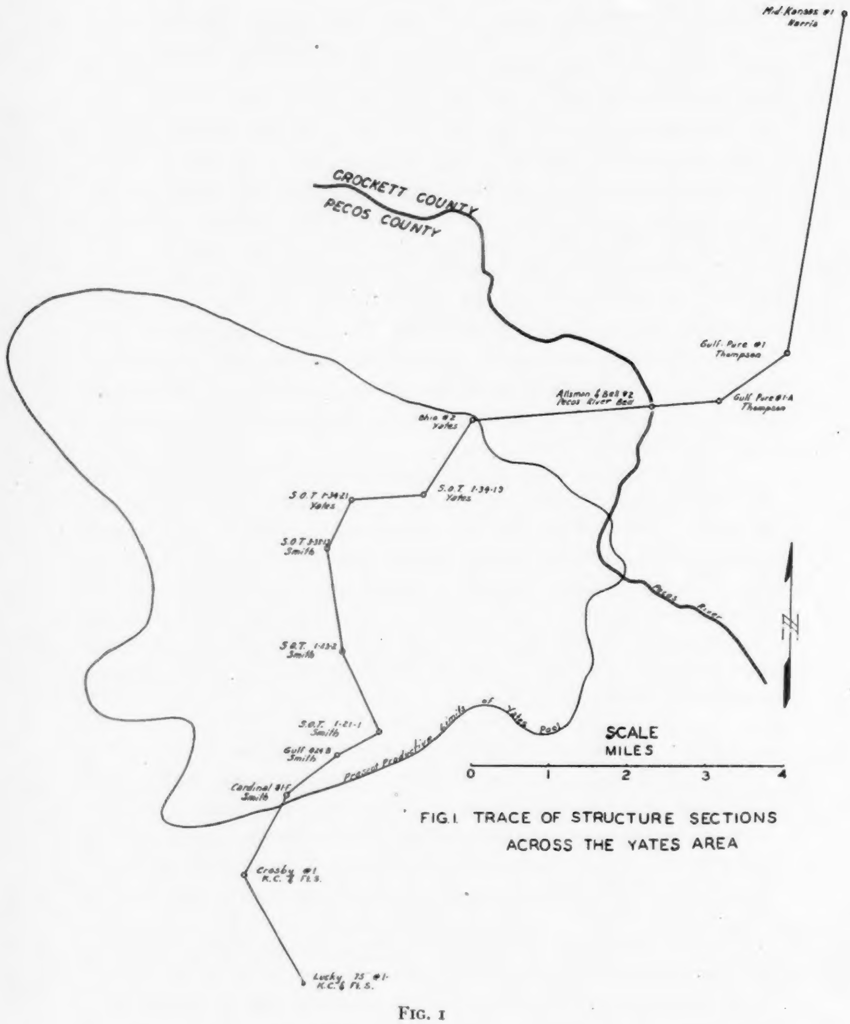

FIG. 1 TRACE OF STRUCTURE SECTIONS ACROSS THE YATES AREA

FIG. 1

Alignment of the fourteen wells used in the sections is indicated on the Yates area map (Fig. 1). The southwest wells are in the Sheffield channel; the northeast ones in the Midland basin. A single series of wells is sufficient to illustrate the salient historical features. The same wells are used in all the sections to allow consistent comparisons.

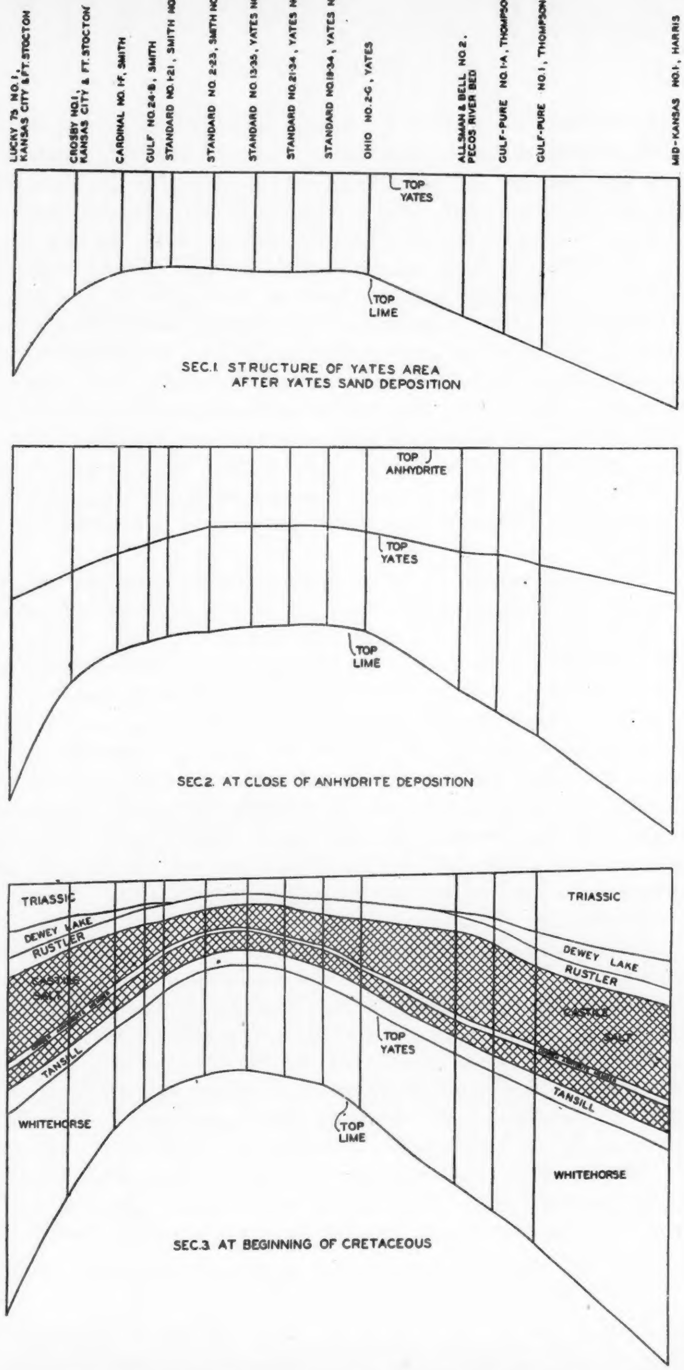

FIG. 2.—Structure sections 1, 2, and 3. Same scale as in Figure 3.

In drawing the sections, it was first assumed that a thin, widespread sandstone like the Yates must have been deposited on an almost level sea floor. When the Yates sand is restored to this assumed primary position, section 1 (Fig. 2), the "top of lime" rises in a distinct arch near the center of the section. The arch marks the southeastern tip of the Central Basin platform, with the low Sheffield channel on the south and the Midland basin on the northeast. The limestone ridge is largely a depositional reef feature rather than being entirely a result of compressive folding. The arch is underlain by a thick section of solid limestones presumably resting on a positive element of older rocks. The lateral basins are negative structural elements and their sediments consist largely of compressible clastics. The measurable increase in the height of the ridge throughout the later Permian and Triassic may, therefore, be due to static adjustments and to differential compaction rather than to direct vertical uplift.

Construction of the remainder of the sections is based on section 5 (Fig. 3), which shows the structure and stratigraphy below the top of the Basement sand as it now is. On this section it may be noted that the highest points on the top of the Basement sand northeast of the dome, on top of the dome, and southwest of the dome can be connected by a straight line. Intermediate areas sink several hundred feet below the regional slope. The sinking took place after the deposition of the Basement sand and, since it was not accompanied by uplift or distortion in the pre-Castile section, is clearly due to post-Cretaceous solution of the underlying salt. The lows are segments of a ring syncline that completely encircles the Yates dome, and it is this solution syncline that controls the observable surface structure of the area.

On the same section it may be noted that there is a lense of pre-Basement sand, Cretaceous clastics underlying the crest and upper flanks of the dome. Apparently these sands and shales were deposited in, and completely filled, an older solution valley similar to that now exposed at the surface. In order to reconstruct this lense to its original position, Section 4 was constructed with the Basement sand restored to its original level position. To do this and leave no gaps in the section, it was necessary to restore the salt dissolved out by post-Cretaceous solution. This salt is shown by fine cross-hatching.

The next step was to reconstruct the level surface of the Wichita paleoplain[5] by raising the surface of the Triassic to the level of the regional slope determined from the end wells of the sections which

[5] R. T. Hill, "Geography and Geology of the Black and Grand Prairies, Texas," *U. S. Geol. Survey Ann. Rept. 21* (1901), pp. 363–67.

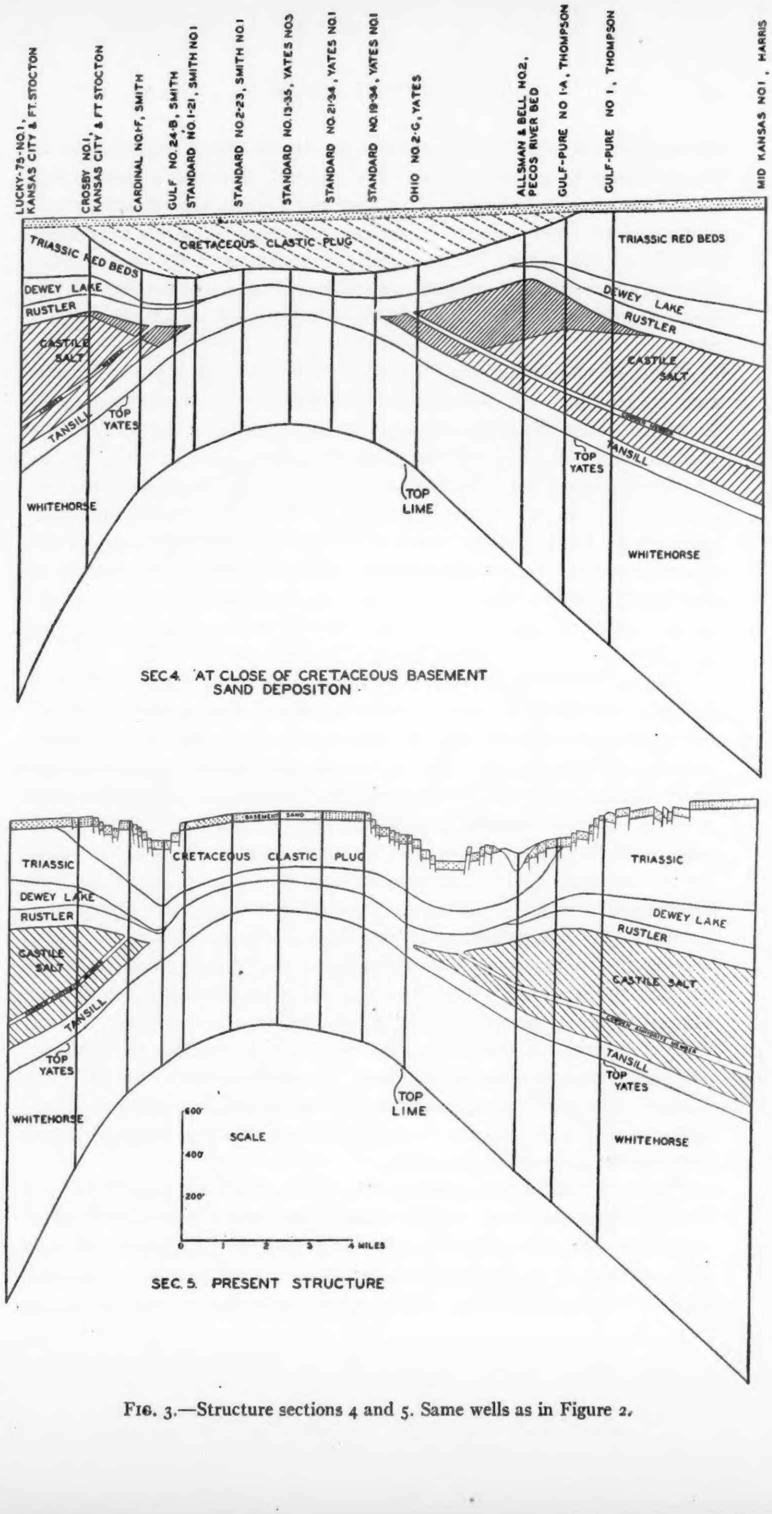

FIG. 3.—Structure sections 4 and 5. Same wells as in Figure 2.

lie outside the solution-disturbed zone. In restoring this surface it was necessary to add a layer of salt completely across the crest of the dome and equal in thickness to the lense of pre-Basement sand clastics. This reconstruction is shown in section 3. The final step was to remove the Triassic and upper Permian redbeds and restore the top of Permian anhydrite to the original flat position that it occupied at the close of anhydrite deposition. This reconstruction is shown in section 2.

Interpreted and restored in this way, the original evaporite section is much thinner over the crest of the "high" than in the adjacent "lows." A comparable thinning of the salt section over undisturbed positive areas is noted in many other parts of the Permian basin. Usually a thin section such as this is regarded as a characteristic phenomenon associated with buried hills, of which the Yates dome is an example. As there is no evidence of compressive folding between the deposition of the Yates sand and the top of anhydrite, the warping of the "lime" and Yates sand that occurred during this interval is assumed to be due to static causes, such as differential settling and compaction.

The third section was constructed on the assumption that post-Triassic, pre-Cretaceous erosion reduced the surface of West Texas to a peneplain and that any limited segment of this surface can be represented by a straight line. The upper Permian redbeds present in the lateral basins thin to a feather-edge and disappear on the flanks of the "high." It is probable that these beds, possibly in reduced thickness, were deposited across the crest but were removed by early Triassic erosion. The Triassic redbeds are also thinner over the Yates high than elsewhere in the area. Most of this thinning is apparently due to post-Triassic erosion rather than to the cutting out of basal beds against a hill in the underlying Permian. This section brings out the structural similarity, at the beginning of Cretaceous time, between the top of the anhydrite, the top of the Yates sand, and the top of the "lime," and illustrates the well known levelling tendency of younger beds to thicken in the "lows" and thin over the "highs." The absence, in any of the upper beds, of over-thickening similar to that of the basal Cretaceous shown in section 5 proves that there had been no extensive period of salt solution.

Salt as a rock in the geologic column is stable when protected from circulating, unsaturated waters. Static waters quickly become saturated and solution ceases. Conditions in the Permian basin province between the close of Permian deposition and the end of Jurassic suggest semi-aridity, with the flat areas only slightly eroded during

development of the Wichita paleoplain. Triassic and Jurassic ground waters accumulated under flat, arid surfaces and, judged by the lack of solution around the Yates "high," were locally either static or too highly saturated to remove much salt. Surface drainage during this period was to the west and southwest.

The northward advance of the Cretaceous sea followed a warping and readjustment of most of the older land surface. This movement was sharpest along the borders of the older, positive areas, such as the Yates "high," where the cracking of the thin, protective shell exposed the underlying, upper Permian salts to solution. The early Cretaceous regional warping also steepened the slope and started large quantities of fresh ground water moving seaward from the high areas on the north and west. These waters, travelling through porous zones in the near-surface rocks, followed the open joints and cracks downward to the salt and then, forced upward and onward by the hydrostatic head, continued on their way to the sea as brines. Solution, followed by slumping, opened additional channels until all the salt on the crest of the high was removed. The remains of the clastic cap and the insoluble material of the salt section sagged to form a broad, synclinal valley about 300 feet deep directly over the crest of the Yates sand "high." Solution progressed far enough down the flanks of the structure for the anticline in the underlying, non-soluble rocks to be reflected as a broad, low hill in the center of the synclinal valley. These relationships are pictured in the fourth section (which also shows by means of fine cross-hatching the additional areas of salt that were removed during the second period of solution in the late Tertiary or Pleistocene).

The lateral, asymmetrical pseudo-anticlines that overlay the basinward margins of the salt solution area intermediate between the crest of the older structure and the bottom of the adjacent synclines, were the outstanding surface structural features at this time. The post-salt sediments were poorly consolidated and slumped down the slope as soil creep or as mud flows. Solution was eventually checked when the face of the salt cliff was completely masked with impervious clays and muds. This may have taken place only with the filling of the solution valley by later sediments.

Early Cretaceous solution was not limited to the Yates area but occurred extensively along the south edge of the Permian salt basin and along the flanks of the Fort Stockton "high." Most of the solution troughs were connected and the surface drainage was concentrated in these channels. As the sea advanced and the land subsided the streams built the bottoms of the channels to grade. Sedi-

ments consisted of muds, sands, and gravel washed in from outside, and of gypsum either washed in or precipitated in place. The fairly uniform bedding of the valley fill resembles lake or tidal estuary rather than stream deposits. Gypsum, *chara oogonia*, and ostracods present in the muds suggest brackish waters. Most of the fossils found in the channel deposits are also present in Glen Rose beds of adjacent areas.

The solution syncline over the crest of the Yates dome was completely filled with a plug of non-marine clastics before the advance of the Cretaceous sea. The first marine beds are the Basement sands, regarded by Adkins as Paluxy.[6] The clastic plug and overlying sands are shaded in on section 4, which pictures the area at the close of Basement sand deposition.

Differential compaction and static settling practically ceased before the advance of the Cretaceous sea and, except for regional uplift, the Yates area has maintained remarkable stability ever since. A slight warping in late Tertiary or Pleistocene again exposed the salt to solution. By necessity, solution was limited to the marginal areas during this second attack. The Cretaceous beds on the crest of the dome were undisturbed because they rested on an insoluble clastic plug. The slumping of the unsupported sediments around this plug developed the ring syncline responsible for the present surface structure. The rigid Cretaceous limestones yielded by faulting. The approximate position of the major faults is shown in section 5, which pictures the structure as it is at present. The position of the surface faults was determined from detailed field maps and aerial photographs. The photographs show hundreds of small faults not recognized in the field.

Solution was more pronounced on the north, east, and south margins of the high, where the salt section was thick, than on the west where the salt was originally thin and most of it had previously been removed. The solution syncline developed by the second period of solution is still largely unfilled and has determined the course of the Pecos River around the north and east edges of the dome. Proof that the present surface structure is due to solution rather than folding is furnished by the fact that nowhere on the crest of the structure does the Basement sand rise above the regional slope determined from surrounding, undisturbed areas.

[6] W. S. Adkins, personal communication.

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OLDER ROCKS OF VAN HORN REGION, TEXAS[1]

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ABSTRACT

Some new facts are given, based on recent detailed surveys, regarding the pre-Cambrian, possible Cambrian, and early Ordovician rocks of the Van Horn region. A geosyncline existed here in later pre-Cambrian time, and in this a thick mass of sediments accumulated, constituting the Allamoore and Hazel formations. These were afterwards deformed, and were overridden from the south by a thrust block of an older formation, the Carrizo Mountain schist. After the deformed rocks were deeply eroded, the clastic, unfossiliferous Van Horn sandstone was laid down over them. Its age is unknown, but may be late pre-Cambrian or early Cambrian. It was tilted, faulted, and eroded before the first marine Paleozoic deposits were spread over it. These are of early Ordovician age, and correlate with the Bliss sandstone farther west. The type Bliss has hitherto been classed as Cambrian, but paleontological evidence for this is questionable. If the suggested correlation is correct, wide areas in western Texas and southern New Mexico, where the Bliss is the basal Paleozoic formation, may never have been covered by the Cambrian seas.

INTRODUCTION

A detailed study of the Sierra Diablo region, northwest of Van Horn, Texas, has recently been completed for the Geological Survey. The results will appear later in a Survey publication. In the meantime, the writer plans to describe some features of the Permian rocks of the mountains in a paper in a later number of this *Bulletin*. Studies are also in progress on the Ordovician and other older Paleozoic rocks by Josiah Bridge and Edwin Kirk, and a résumé of their results will be published.

Besides these two subjects, there are many others of geological interest in the area, on which much new information has been obtained. One of these is dealt with briefly in the present paper; namely, the older, or pre-Ordovician and early Ordovician rocks. The pre-Ordovician rocks are largely of pre-Cambrian age, but some beds of possible Cambrian age are present.

The pre-Ordovician rocks crop out in a wide area in the low foothills south of the Sierra Diablo (Fig. 1), a region which is structurally the highest part of trans-Pecos Texas.[3] They extend from Van Horn on the east to Eagle Flat on the west, and from Victorio Peak on the north to the Van Horn Mountains, south of Van Horn, on the south. The main area of exposure is in the hills shown as the Carrizo Mountains on the Van Horn topographic sheet.

[1] Published by permission of the director of the Geological Survey, United States Department of Interior. Presented orally before West Texas Geological Society at Midland in January, 1939, and by title at the Oklahoma City meeting of the Association in March, 1939.

[2] Geological Survey, United States Department of Interior.

[3] C. L. Baker, "Structural Geology of Trans-Pecos Texas," in "Geology of Texas," Vol. 2, *Texas Univ. Bull. 3401* (1935), pp. 182–85.

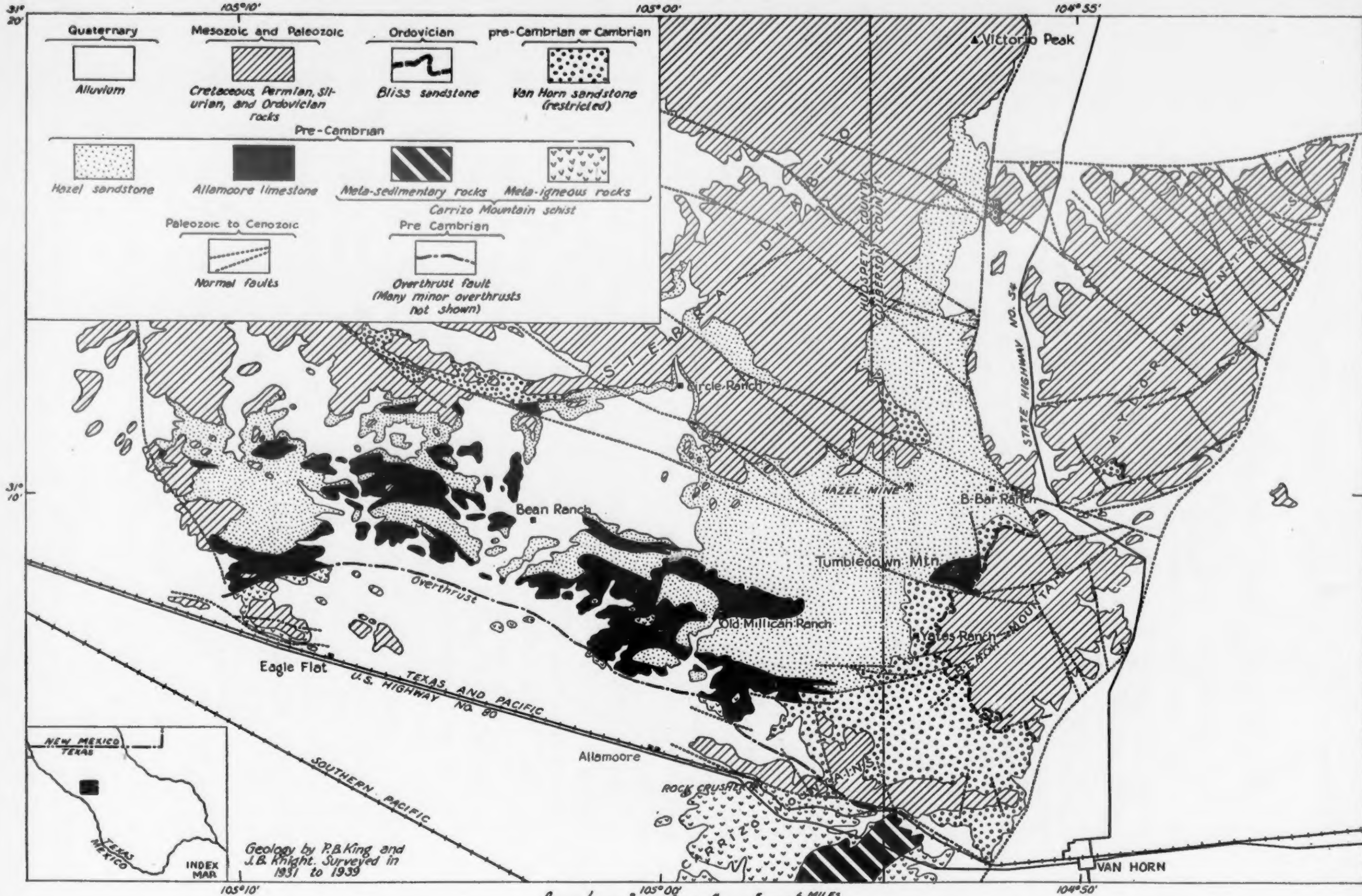

FIG. 1.—Geologic sketch map of area northwest of Van Horn, Texas, showing distribution of older rocks, and location of places mentioned in text.

The pre-Ordovician rocks include highly metamorphosed schists of sedimentary and igneous origin, and also slightly metamorphosed or unaltered limestones, pyroclastics, conglomerates, and sandstones. Over wide areas they are intensely deformed, but in others beds of the same age are nearly flat. A number of major unconformities are present, some of which indicate times of mountain making. The pre-Ordovician rocks are overlapped by various later formations, including beds of Ordovician, Pennsylvanian or Permian, and Cretaceous ages. Their exposures are interrupted by remnants of the later formations, in part downfaulted, and by wide areas of alluvium.

Earlier observations on the pre-Ordovician rocks have been published by Von Streeruwitz[4] and Dumble[5] of the Texas Geological Survey, and by Richardson[6] of the United States Geological Survey. The views of these geologists need not be discussed in detail, but they are suggested in the table that follows. Hitherto, the standard classification of the rocks has been that of Richardson, but as indicated by the table, a number of changes are here proposed.

Von Streeruwitz, 1891	*Dumble, 1902*	*Richardson, 1914*	*This Paper*	
Carboniferous	Silurian	El Paso limestone	El Paso limestone	Ordovician
Diabolo sandstone	Potsdam sandstone	Van Horn sandstone	Bliss sandstone	
			Van Horn sandstone	Pre-Cambrian or Cambrian
	Hazel sandstone	Millican formation	Hazel sandstone	Pre-Cambrian
(Not classified)	Texan marble (placed above Hazel sandstone)		Allamoore limestone	
Carrizo schist	(Not discussed)	Carrizo formation	Carizzo Mountain schist	

CARRIZO MOUNTAIN SCHIST

The Carrizo Mountain schist[7] includes the oldest rocks of the region. Its main exposure is in the barren ridges west of Van Horn,

[4] W. H. Von Streeruwitz, various annual reports of Texas Geological Survey; for example, *2nd Ann. Rept., 1890* (1891), pp. 681–83.

[5] E. T. Dumble, "The Red Sandstone of the Diablo Mountains," *Texas Acad. Sci. Trans.*, Vol. 4, Pt. 2 (1902), pp. 1–3.

[6] G. B. Richardson, "Reconnaissance in Trans-Pecos Texas North of the Texas and Pacific Railway," *Texas Univ. Bull. 23* (1904), pp. 24–29.

———, "Van Horn," *U. S. Geol. Survey Geol. Atlas Folio 194* (1914), pp. 3–4.

[7] The original name of the formation, as indicated in the table, has been changed in recent reports of the Geological Survey and Texas Bureau of Economic Geology to avoid conflict with the Carrizo sand (Tertiary) of the Texas Coastal Plain.

south of the Texas and Pacific Railway. Small inliers of the formation farther south have been described by Baker,[8] and many others have been discovered during the present study north of the Texas and Pacific Railway between Allamoore and Eagle Flat stations[9] (Fig. 1).

The Carrizo Mountain schist consists of a number of contrasting types of metamorphic rocks, which can be separately mapped over wide areas. These fall into two main groups, one of which appears to lie stratigraphically beneath the other. The lower group is largely of igneous origin, and includes rhyolites and greenstones with varying degrees of schistosity, as well as various other schists of undetermined origin. These are well exposed along U. S. Highway 80 for several miles southeast of Allamoore.

The upper group is largely of sedimentary origin, and forms a synclinal belt several miles wide that extends northeastward entirely across the Carrizo Mountains. This crosses U. S. Highway 80 near the Culberson-Hudspeth County line (Fig. 1). The basal unit is a gray, cross-bedded quartzite at least 1,000 feet thick that stands in high, hogback ridges. In one of the cuts on the highway not far east of the county line, its bedding surfaces are ripple marked. Above this is a thick succession of slates, banded cherts, and limestones. Metamorphism of the sedimentary rocks is of comparatively low grade. No evidence has been obtained as to whether the sediments are conformable or unconformable on the meta-igneous rocks beneath, or whether they are intruded by them.

The rocks of sedimentary origin in the Carrizo Mountain schist may not be very different in age from those of the Allamoore limestone, the next formation to be described. They may have been formed during the same cycle of deposition, with the sedimentary rocks in the Carrizo Mountain representing the initial deposits, and those in the Allamoore limestone the later deposits. This suggestion is difficult to prove or disprove, since the two crop out in separate areas, and since there are no fossils for guidance. However, the types of rocks present, and the degree of metamorphism and deformation are similar.

The Carrizo Mountain schist is cut everywhere by veins of quartz and pegmatite, and at the Mica Mine south of Van Horn it is intruded by large masses of pegmatite and pegmatitic granite.[10]

The Carrizo Mountain schist is overthrust northward on the

[8] C. L. Baker, "Exploratory Geology of Southwestern Trans-Pecos Texas," *Texas Univ. Bull. 2745* (1927), pp. 7–8.

[9] P. B. King, "Outline of Structural Development of Trans-Pecos Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19 (1935), pp. 224–26.

[10] C. L. Baker, *op. cit.*, pp. 7–8.

succeeding Allamoore limestone. The thrust contact, dipping generally southward, has been traced discontinuously in an east-southeastward direction for a distance of 15 miles, or from Eagle Flat on the west to a point a few miles west of Van Horn on the east (Fig. 1). Near the middle of its observed trace, 3 to 4 miles north-northwest of Allamoore, several klippen, or outliers of the overthrust mass, lie on the Allamoore limestone and stand a mile or more north of the main trace of the thrust.

The rocks adjacent to the thrust plane belong to the lower, or meta-igneous part of the Carrizo Mountain schist, and are largely of rhyolitic composition. For some miles south of the outcrop of the thrust they appear to have been cataclastically altered, so that phenocrysts are crushed, and minerals are drawn out in long streaks or lineations within the rock. These features apparently have resulted from differential motion of one part of the mass over the other. Close to the thrust, rocks of this sort grade into mylonite, a dense, flinty rock produced by extreme granulation. This contains closely set, straight laminae, which superficially are not unlike the laminae of sedimentary origin in the Castile anhydrite.

Much further study is needed before this cataclastic metamorphism can be successfully explained. Preliminary observations in the field suggest, however, that it was related in origin and in time to the overthrusting of the Carrizo Mountain schist onto the other pre-Cambrian rocks to the north.

†[11]MILLICAN FORMATION OF RICHARDSON

The succeeding rocks, like the Carrizo Mountain schist, appear to be of pre-Cambrian age, but they are dominantly of sedimentary origin and relatively unmetamorphosed, although they are greatly deformed in places. They include red sandstone, conglomerate, limestone, and various sorts of volcanic rocks. To the whole succession Richardson gave the name Millican formation, but the term Hazel sandstone had previously been given to the red sandstone by Dumble.

In a belt several miles wide north of the overthrust mass of Carrizo Mountain schist, the various sedimentary and volcanic rocks of the succession are complexly folded, so that the stratigraphic sequence is difficult to make out. In places, conglomerate lies on limestone and volcanics, and passes upward into red sandstone. In others, notably on Tumbledown Mountain west of Beach Mountain (Fig. 1), limestone and volcanics lie on sandstone. The structure of the folded

[11] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the Geological Survey.

belt is so difficult to decipher that Richardson was justified in grouping the whole succession together.

From detailed study it appears, however, that the section actually consists of two distinct parts, an older formation of limestone and volcanics, and a younger of conglomerate and red sandstone. At localities where limestone lies on sandstone, there is good evidence that it reached its present position by overthrusting or overfolding. Moreover, the conglomerates interbedded in the red sandstone consist almost entirely of fragments of limestone and volcanics, indicating not only that the latter are older but that the two units are separated by a marked unconformity.

For these reasons, it now appears that the †Millican formation of Richardson should be divided into two formations, and it is recommended that the name be abandoned. It could not be restricted to a part of the former unit without greatly changing its original meaning. It could be retained as a group term for the two formations, but the writer believes this is undesirable, since the sediments in the two formations are so distinct in their nature, and since the unconformity between them indicates that they were formed during unrelated times of deposition.

For the upper of the two formations, Dumble's term Hazel sandstone is available, and is used in this paper. For the lower, no name has previously been given except Dumble's term Texan marble, which was imported from the Llano area of central Texas, where it had been used by Comstock.[12] This term is no longer used in the type area, with which, moreover, correlations are doubtful, and a new name for the beds near Van Horn is desirable. For them, the term Allamoore[13] limestone is here proposed, the name being derived from the village of Allamoore, 11 miles west of Van Horn on the Texas and Pacific Railway and U. S. Highway 80 (Fig. 1). The village itself stands on alluvium, but outcrops of the limestone rise in prominent hills a few miles north.

ALLAMOORE LIMESTONE

The Allamoore limestone is characteristically thin-bedded, of blue, gray, or brown color, with nearly all the beds seamed at regular intervals by thin bands of chert. Differential weathering of chert and limestone gives the outcrops a striking ribbed appearance. Parts of the limestone are dark gray or black. Specimens of such rock analyzed

[12] T. B. Comstock, "A Preliminary Report on the Geology of the Central Mineral Region of Texas," *Texas Geol. Survey 1st Ann. Rept. 1889* (1890), pp. 276–82.

[13] This name is spelled in two ways, Allamoore for the post office, Allamore for the railroad station. In this paper, the spelling given to the post office is adopted.

in the chemical laboratory of the Geological Survey indicate that the color is due to organic matter, not unlike that in the bituminous limestones of the Paleozoic. This suggests the existence of life during the deposition of these ancient rocks. There are, however, few indications of fossils, although certain features in the limestones may be of algal origin.[14]

Associated with the limestone are great masses of volcanic rocks. These include diabasic flows, in part amygdaloidal, in part massive, and various pyroclastic rocks, such as breccias and fine-grained, well bedded tuffs. The volcanics are interbedded with the limestone in thin to thick members, indicating that limestone deposition and volcanic activity took place in rapid alternation.

The Allamoore limestone is exposed only in the strongly folded belt north of the overthrust mass of Carrizo Mountain schist. Its rocks are so disturbed that it has not been possible to make out the details of its succession or to determine its thickness. Over wide areas, however, its beds stand nearly vertical, so that its thickness is perhaps to be measured in thousands of feet.

HAZEL SANDSTONE

Resting on the Allamoore limestones and volcanics and forming the basal part of the succeeding Hazel sandstone, is a thick mass of conglomerate. Because of the great amount of faulting and shearing near the Allamoore-Hazel contact, one can not determine the relations of the two formations from the exposures. The conglomerate, however, indicates that they are separated by an unconformity. It consists largely of limestone fragments, ranging from pebbles to large, angular blocks 6 feet or more across. The large fragments are most abundant in the lower part, but are fairly common 500 feet or more above the base. The Allamoore limestone thus appears to have been raised into a land of high relief before Hazel time. The uplift may have been accompanied by metamorphism and folding, because some (but not all) of the limestone fragments are marmorized.

Besides limestone fragments, the conglomerate contains many volcanic rocks, whose various types can all be matched with those found in place in the Allamoore. In addition, in certain areas, there are cobbles and boulders of red rhyolite and red granite, which resemble fragments embedded in the succeeding Van Horn sandstone. These only slightly resemble the rhyolitic rocks in the Carrizo Mountain schist, but are very similar to granites and rhyolites below the

[14] Features seen in the limestones closely resemble some of those figured by C. L. Fenton and M. A. Fenton, "Pre-Cambrian and Paleozoic Algae," *Bull. Geol. Soc. America*, Vol. 50 (1939), pp. 89–126, which are considered by them to be of algal origin.

Paleozoic at the northwest, in the Franklin and Hueco mountains, and near Hueco Pump Station, north of Sierra Blanca.[15] In 1932, the writer reported the apparent occurrence of fragments of Carrizo Mountain schist in the conglomerate,[16] but has seen none since, and is now inclined to doubt that they exist.

Passing upward, the conglomerate is interbedded to an increasing extent with red sandstone, which finally dominates altogether. The sandstone is a very fine-grained, well consolidated rock, marked by thin, dark, cross-bedded laminae. It is cut by numerous joints of various trends and inclinations, which in places tend to obscure the bedding. Toward the south, it dips at high angles, but farther north it lies nearly flat.[17] The sandstone crops out extensively on the southern and southeastern scarps of the Sierra Diablo, where it forms red, rounded slopes below the light gray cliffs of the Hueco limestone. The Hazel Mine, the type locality, lies at the base of one of these slopes (Fig. 1).

The thicknesses of the conglomerate and red sandstone of the Hazel unit have not been measured, but must reach thousands of feet. At many places where the conglomerate stands vertically, it forms belts of outcrop nearly a mile wide, but has undoubtedly been duplicated to a certain extent by folding. North of the Hazel Mine on the escarpment of the Sierra Diablo, the exposed thickness of the red sandstone is at least 2,000 feet, but with neither the base nor top exposed.

STRUCTURE AND STRUCTURAL HISTORY

Some mention has been made of the structure of the formations already described, but it deserves further notice. On the south is the Carrizo Mountain schist, which has been thrust northward across the Allamoore limestone, along a plane which strikes east-southeast. North of the thrust in a belt about 5 miles wide, the Allamoore limestone and Hazel sandstone have been intricately folded and faulted, likewise with an east-southeast strike. Farther north, the Hazel sandstone flattens abruptly, and passes northward with gentle dips beneath the Paleozoic rocks of the Sierra Diablo.

The narrow deformed belt between the overthrust on the south

[15] P. B. King, "Outline of Structural Development of Trans-Pecos Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19 (1935), pp. 226–27.

[16] N. H. Darton and P. B. King, "West Texas and Carlsbad Caverns," *Int. Geol. Cong. Guidebook 31* (1932), p. 21.

[17] Richardson, in the Van Horn folio, states (p. 4) that at the Hazel Mine in the northern area, a decolorized streak in the sandstone indicates that the beds are nearly vertical. The streak is actually developed along joint planes, the same as those followed by the ore body. The writer's own observations indicate definitely that the beds are nearly horizontal in this vicinity.—Philip B. King.

and the flat-lying rocks on the north contains some remarkable structural features, not all of which are easy to interpret. Isoclinal, overturned, and even recumbent folds are undoubtedly present, as well as numerous minor overthrusts. Relations are complicated by the relative incompetency of the volcanic members, the tendency of the limestones to flow under pressure, and the relative competency of the conglomerate members. The folds in the deformed belt are very similar to those in the Paleozoic rocks of the Marathon basin on the southeast.[18] They are of about the same amplitude, and are apparently thrust and overfolded in about the same manner. They are, moreover, strikingly similar in mode of outcrop.

What was the history of the structural features as we now see them? They evidently arose from a geosyncline, much as did the Paleozoic folds of the Marathon basin, but from a geosyncline that was extinguished before the beginning of Paleozoic time. In this, great thicknesses of limestones and volcanics accumulated at first to form the Allamoore deposits, and later on conglomerates and sandstones which formed the Hazel. After the deposition of the Allamoore, the first orogenic paroxysm took place, and caused a radical change in the environment of sedimentation, and the type of sediments laid down. By it, the Allamoore was strongly uplifted, partly metamorphosed, and perhaps folded. It may have caused some of the complex structural features seen in the present outcrops of the Allamoore limestone.

The initial paroxysm did not, however, bring about the overthrusting of the Carrizo Mountain schist, or the greater part of the folding north of the thrust. This took place after Hazel time, since the Hazel is intimately infolded with the Allamoore near the thrust. Moreover, the conglomerate at the base of the Hazel consists almost entirely of fragments derived from the Allamoore, and apparently contains no fragments of the Carrizo Mountain.

The final, or post-Hazel paroxysm caused most of the deformation now seen in the region, but has left no record in the sediments comparable to the basal Hazel conglomerates which resulted from the first paroxysm. At a considerably later time, however, after the folded and faulted rocks were deeply eroded, a clastic formation was spread over them. This is the Van Horn sandstone, the next to be described. In this, for the first time in the succession, occur fragments of the Carrizo Mountain schist, including rocks of cataclastic facies, which may have been altered at the time of the overthrusting.

[18] P. B. King, "The Geology of the Marathon Region, Texas," *U. S. Geol. Survey Prof. Paper 187* (1938), pp. 119–38.

VAN HORN SANDSTONE

The Van Horn sandstone, as defined by Richardson, included red, arkosic sandstones below, and white, quartzose sandstones above. The two parts were supposed to be conformable. Worm tubes, or *Scolithus*, that are common in the upper sandstones, were believed to indicate a Cambrian age for the formation. Subsequent work has shown, however, that the two parts of the original formation are separated by a well marked unconformity. The beds above, as indicated by fossils, are of Ordovician age, but the age of the beds below is unknown. Since the lower, red, arkosic part of the original formation is the thickest and most characteristic, it is here proposed to restrict the name Van Horn sandstone to it. For reasons that will be given later, the upper part is here termed the Bliss sandstone.

The Van Horn sandstone, as thus restricted, is a thick-bedded, red, arkosic sandstone, containing numerous beds of conglomerate, having a maximum thickness of about 700 feet. It closely resembles the preceding Hazel sandstone. It differs from the Hazel in the different composition and greater rounding of the conglomerate fragments, and in the coarser texture, slighter consolidation, and thicker bedding of the sandstones. Geologists to whom the writer has shown it in the field have compared it with the Triassic Newark series of the eastern states, and the late Paleozoic Fountain formation of Colorado.

The conglomerates in the Van Horn sandstone consist of smoothly rounded pebbles and cobbles made up largely of igneous rocks, which are chiefly red granites and red rhyolites. There are also fragments of basic igneous rocks, vein quartz, Hazel sandstone, and Carrizo Mountain schist. Fragments of Allamoore limestone are absent, although they are the dominant constituent of the preceding Hazel conglomerates. At one place, west of the Circle Ranch (Fig. 1), the Van Horn contains granite boulders, which, while perfectly rounded, reach 3 feet in diameter. The granites and rhyolites which form the dominant fragments in the conglomerate can not be matched with any rocks now exposed in the region. Like those which occur more rarely in the Hazel conglomerates, they most closely resemble granites and rhyolites that lie beneath the Paleozoic some distance northwest. Probably this area stood as a highland at the time of Van Horn deposition.

The sandstones in the Van Horn are coarse-grained and arkosic, and of red, red-brown, or purplish color. Many layers are cross-bedded, with the cross beds dipping generally southward. The formation crops out at present only in disconnected, basin-like areas, largely

as a result of the overlap of various Paleozoic formations that lie on it. One might suppose that these basins mark approximately the areas in which it was originally deposited. However, its conglomerate fragments are dominantly not of local origin, and the cross-beds maintain their southward dip, regardless of the dip of the beds into the basins. The Van Horn was thus probably spread as a continuous sheet over the entire region.

The Van Horn sandstone rests on the truncated edges of the Allamoore and Hazel formations, and was deposited long after they were folded. Its own beds are, however, tilted at angles up to 30°, and their edges were truncated before the succeeding Bliss sandstone was laid down over them. Moreover, on Tumbledown Mountain west of Beach Mountain, the formation was faulted before Bliss time. On two faults on the east and south sides of the mountain (Fig. 1) it is dropped against the Allamoore and Hazel formations, and the Bliss extends across the faults to lie on the Allamoore on the upthrown sides.

The age of the Van Horn sandstone is unknown. It was originally classed as Cambrian on the basis of worm tubes in the succeeding Bliss sandstone (now known to be of Ordovician age). Because it was tilted, faulted, and deeply eroded before the Bliss was laid down over it, it must be much older. It does not resemble any Upper Cambrian sediments elsewhere. These consist generally of cleanly washed sands, laid down on a nearly peneplained surface. The Van Horn sandstone consists of poorly sorted sands, laid down in a region of high relief, probably in a continental environment. Van Horn sedimentation seems almost to be a resumption of Hazel type of sedimentation, after an interruption caused by the post-Hazel orogeny.

The writer's own belief is that if the Van Horn sandstone is Cambrian, it is probably Lower Cambrian. It is within the bounds of possibility, however, that it is of late pre-Cambrian age. For the present it seems best to classify it as of pre-Cambrian or Cambrian age.

BLISS SANDSTONE

The quartzose sandstone, here termed the Bliss, which was considered to be an upper member of the Van Horn formation by Richardson, is the oldest marine Paleozoic deposit of the region, and is of early Ordovician age.

The formation crops out most prominently on the sides of Beach Mountain, the only other exposures being a few small patches in the Baylor Mountains to the north (Fig. 1). Its average thickness is

about 125 feet, and it consists of rather thinly bedded quartzose, non-calcareous sandstone, many of whose beds are penetrated by vertical worm tubes, or *Scolithus*. As already noted, it lies unconformably on the Van Horn sandstone, and in the basal few feet contains pebbles and arkosic sand re-worked from that formation. It appears to be separated from the overlying El Paso limestone by a disconformity. The contact between them is sharp and clearly marked, and although the basal El Paso contains beds of quartzose sandstone, these are all calcareous and thick-bedded.

Ordovician gastropods were discovered in the Bliss sandstone of the Van Horn region by C. L. Dake in the spring of 1931, and were seen by J. B. Knight and the writer the following summer. After this discovery, and the finding of the unconformity between the Bliss and the Van Horn (restricted), the writer concluded that the unit was simply the basal member of the El Paso limestone, and that the Van Horn-El Paso contact had been drawn too high by Richardson.

This appears, however, not to be the case. The basal El Paso limestone at the type section in the Franklin Mountains contains the *Piloceras-Calathium* faunal assemblage, of upper Beekmantown age.[19] The same zone occurs directly above the Bliss sandstone at Van Horn. According to Bridge, it is equivalent to the upper part of the Ellenburger limestone of central Texas.[20]

According to identifications by Josiah Bridge, the fossils of the Bliss sandstone of the Van Horn region consist of *Scolithus*, various unidentified linguloid brachiopods, abundant gastropods of the genera *Eccyliomphalus* and *Ophileta*, and rare trilobites of the genus *Hystricurus*. All are poorly preserved in the sandstone, but the form of the gastropods is distinctive and unmistakable. The trilobite is a form unknown in the Cambrian. Bridge concludes, with the assent of Ulrich, Kirk, and Resser, that the fauna is not of Cambrian, but of Beekmantown age, although it belongs in a considerably lower zone of the Beekmantown than the basal El Paso, and correlates with part of the beds in the Ellenburger limestone of central Texas that are of Gasconade age. Whether there is a faunal as well as a physical break between the Bliss and El Paso in the Van Horn region is not yet proved. In the vicinity of Beach Mountain, the *Lecanospira* fauna

[19] Edwin Kirk, "The Lower Ordovician El Paso Limestone of Texas and Its Correlatives," *Amer. Jour. Sci.*, 5th Ser., Vol. 28 (1934), p. 450.

[20] For a preliminary discussion of this formation, see C. L. Dake and Josiah Bridge, "Faunal Correlation of the Ellenburger Limestone of Texas," *Bull. Geol. Soc. America*, Vol. 43 (1932), pp. 725–48. This has to a certain extent been superseded by later work by Bridge.

appears to be absent, but this fossil does occur at one locality in the Diablo Plateau, northwest of the area shown in Figure 1.[20a]

In the type section of the El Paso limestone in the Franklin Mountains, its basal beds, with the *Piloceras-Calathium* zone, rest on the type section of the Bliss sandstone. This formation has long been classified as of Upper Cambrian age, on the basis of linguloid brachiopods collected in the Franklin Mountains, and identified by Walcott.[21] Aside from worm tubes, the formation contains no other fossils. Recently, all the collections that have been made from the Bliss in the type area have been examined by Bridge. He finds nothing in them that definitely indicates a Cambrian age. On the contrary, the linguloid brachiopods from the Bliss of the type area are not unlike those which occur in the Bliss at Van Horn in association with Ordovician fossils.

Physical evidence suggests that the formations in the two areas are the same.[22] Each is a bed of quartzose, marine sandstone a few hundred feet thick, the basal marine deposit of the area, laid down on a peneplaned surface. Each is succeeded, perhaps disconformably, by the basal El Paso limestone, containing the *Piloceras-Calathium* zone. Although the paleontologic evidence does not prove such a correlation, it is not opposed to it. Evidence for correlation seems sufficiently definite so that the beds at Van Horn should be termed the Bliss, and this formation be reclassified as of Ordovician age.

This correlation opens up some interesting questions in paleogeography. The Bliss is the basal Paleozoic formation over a wide area in northern trans-Pecos Texas and southern New Mexico. If it is of basal Ordovician, rather than of Upper Cambrian age, this area was land during Cambrian time, and was not covered by the Upper Cambrian sea. In this area, only one formation can be classed even dubiously as Cambrian, the Van Horn sandstone. As we have seen, this was probably a continental rather than a marine deposit, and must be much older than Upper Cambrian.

On the east, the nearest proved Upper Cambrian is in the Llano area of central Texas (Hickory, Cap Mountain, Wilberns, and basal

[20a] On a visit to the area in the autumn of 1939, and after this paper was prepared, Mr. Bridge reports that he collected fossils on Beach Mountain, in the basal El Paso, immediately above the Bliss, which appear to be of Gasconade age. If this preliminary identification proves to be correct, little or no time hiatus separates the Bliss from the El Paso.

[21] G. B. Richardson, "El Paso," *U. S. Geol. Survey Geol. Atlas Folio 166* (1909), p. 3.

[22] A similar conclusion was reached independently by M. B. Arick, "Early Paleozoic Unconformities in Trans-Pecos Texas," *Texas Univ. Bull. 3501* (1936), p. 118.

Ellenburger)[23] and in the Marathon basin of southeastern trans-Pecos Texas (Dagger Flat).[24] The fossils of the Dagger Flat sandstone are meager and poorly preserved, but seem to be definitely Cambrian since they include the trilobite *Agnostus*. Toward the west, the nearest proved Upper Cambrian is the Abrigo limestone of southeastern Arizona. According to Bridge, its faunas are sufficiently distinct from those of central Texas to suggest a roundabout, rather than a direct, connection between them. This evidence tends to confirm the conclusion reached above, that the intervening West Texas-New Mexico area was land during Upper Cambrian time.

ACKNOWLEDGMENTS

The writer wishes to express his indebtedness to his co-worker in the field, J. B. Knight, who is equally responsible for many of the ideas presented herein. Josiah Bridge has also aided in the development of the ideas, has seen the rocks with us in the field, and has identified the fossils. Field studies of the metamorphic rocks have been made partly in company with Earl T. Ingerson, and it is hoped that he can continue their study at some time in the future.

[23] C. L. Dake and Josiah Bridge, *op. cit.*, pp. 726–29.

[24] P. B. King, "Geology of the Marathon Region, Texas," *U. S. Geol. Survey Prof. Paper 187* (1938), p. 23.

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PALEOZOIC STRATIGRAPHY OF FRANKLIN MOUNTAINS, WEST TEXAS[1]

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ABSTRACT

The Franklin Mountains are within a region that is bounded on the east by Longitude 104° 30′ W., on the west by Longitude 109° W., on the south approximately by Latitude 31° N., on the north approximately by Latitude 34° N. From just north of El Paso the Franklin Range trends almost parallel with the 106° 30′ W. meridian to a point about 4 miles north of the Texas-New Mexico boundary.

The Franklin Mountains are eroded block mountains typical of the Basin-and-Range province of southwestern United States. The west side constitutes a dip slope, while the east side is a scarp formed by a strike fault.

The accompanying diagrams consist of a stratigram, which shows both the stratigraphy and the geographic location, and two columnar sections, one from Silver City, New Mexico, to El Paso, Texas, the other from the northern end of the Oscura Mountains in New Mexico to the southern end of the Franklin Mountains in Texas.

The Paleozoic stratigraphic section is approximately 8,000 feet in thickness and includes Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian sediments.

The Cambrian rests on the pre-Cambrian, which, in places, is represented by the Red Bluff granite (new name) and in other places by the Lanoria quartzite.

The Magdalena formation is described in special detail. It consists primarily of thin-bedded, light gray to black limestone, which, for convenience, is divided into the following three members: the La Tuna at the base, the Berino, and the Bishop's Cap at the top. The characteristic fossils of certain members are listed.

The Permian is represented by about 650 feet of exposed Hueco sediments. These sediments occur some distance west of the Franklin Range proper and are separated from the exposed Magdalena sediments by alluvial deposits. The contact between the Magdalena and the Hueco has not been seen in the Franklin Mountains. The Permian is overlain by the Comanche in most of the region.

INTRODUCTION

West Texas and the southern half of New Mexico, familiar to all stratigraphers in western Texas, is a most interesting area from the geologist's standpoint. There is probably no other area in the southwest which offers such a complete stratigraphic sequence.

The only geologic study of any consequence of the Franklin Mountains was conducted by G. B. Richardson (1)[3] of the United States Geological Survey and the results were published in 1909.

Some minor adjustments are necessary to bring up to date the correlation of these sediments with those of the immediately surrounding territories. Relatively little detailed work has been done on the Carboniferous sediments of the Franklin Mountains prior to that on which this paper is based.

[1] Prepared, in part, as a Ph.D. thesis, University of Colorado, August, 1937. Read in part, before the Association at El Paso, September 29, 1938. Manuscript received, July 27, 1939.

[2] Associate professor of geology, College of Mines and Metallurgy.

[3] Numbers in parentheses refer to Bibliography at end of article.

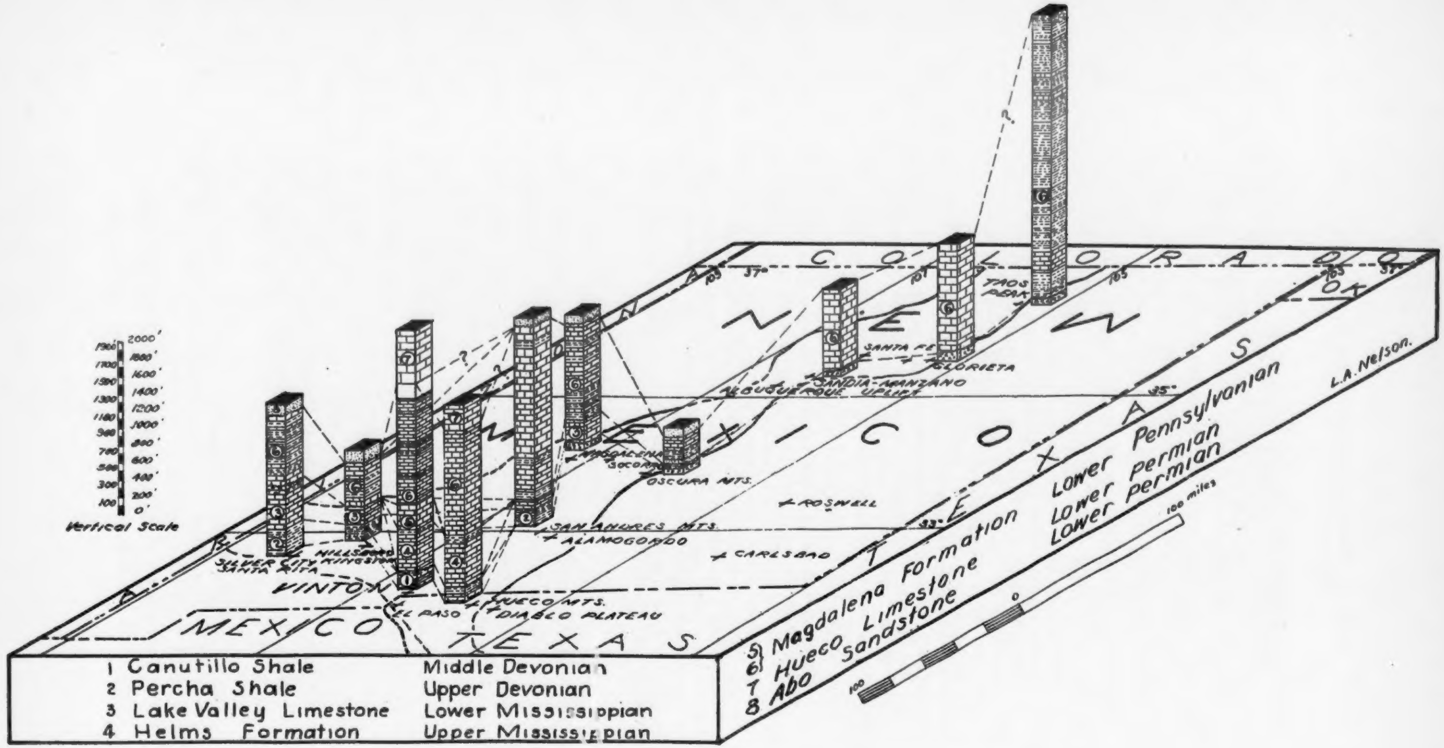

FIG. 1.—Stratigram showing columnar sections with their geographic location.

The primary purpose of this study is an attempt to correct, as far as possible, the errors which were made in the stratigraphy, especially of the Carboniferous of the El Paso region. It is anticipated also that this material will prove valuable in establishing a closer relationship of the Pennsylvanian sediments of the Franklin Mountains with those in other parts of the country.

Location and Topography

The region covered by this report (stratigram, Fig. 1) is bounded on the east by Longitude 104° 30′ West and extends westward to 109° west longitude. The southern boundary is about 31° north latitude and the northern boundary is approximately Latitude 34° North. The mountain ranges within the area have a more or less parallel, almost north-south trend. The Santa Rita and Silver City mountains, however, have a northeast-southwest trend.

The Hueco-Sacramento Mountains are the eastern boundary of the area; they are separated from the Franklin-Organ-San Andres-Oscura Mountains, on the west, by the Tularosa Basin and the Hueco Bolson filled with unconsolidated sediments. The Hueco Bolson has been explored by the drill to a depth of about 5,000 feet without finding a single stratum of consolidated rock.

The Sierra Caballos lie west of the San Andres Mountains, but east of the Rio Grande Valley. West of the Rio Grande Valley lie the Lake Valley Hills and the Black Range Mountains, both of which are separated from the Rio Grande by a vast alluvial terrane; still farther west lie the Santa Rita and the Silver City mountains, which are separated from the Black Range group by the Mimbres Valley.

The mountain ranges just mentioned are characteristic of the Basin-and-Range structural type, the Franklin Mountains being particularly so. No single range reveals a complete stratigraphic section, but the region as a whole includes the greater part of the geologic column.

The Franklin Mountains rise abruptly approximately 3,000 feet above the level of the bolson, attaining an elevation of 7,152 feet above sea-level. These mountains are made up of igneous and sedimentary rocks, the latter dipping from 23° to 45° toward the west. The range plunges northward and disappears beneath the alluvium about 4 miles north of the Texas-New Mexico boundary. The Organ Mountains rise from the bolson a few miles north of the place where the Franklin Mountains disappear. Directly north of the Organ Mountains and separated from them by Organ Pass is the south end of the San Andres Mountains, which continue northward for 80 miles.

The Oscura Mountains lie slightly northeast of the north end of the San Andres Mountains and are separated from them by an offset.

The Rio Grande drains the region, and most of the farming and agricultural activities are carried on in its valley. The climate of the region is semi-arid. In the spring high winds are the rule rather than the exception.

STRATIGRAPHY

GENERAL

The rocks of the region range in age from pre-Cambrian to Recent. They consist mainly of pre-Cambrian granite, rhyolite, and quartzite, Paleozoic and Mesozoic sediments, post-Carboniferous granites, and Tertiary granites and diorites in the form of laccoliths, batholiths, and stock-like masses. Effusive igneous material covers parts of the area.

PRE-CAMBRIAN

Except in the Hueco Mountains, where the Cambrian is the basal formation, the base of the stratigraphic column is the pre-Cambrian. The pre-Cambrian of the Franklin Mountains consists of granite (for which the name *Red Bluff* is proposed, and which occurs at Red Bluff Park in McKelligan Canyon) and the Lanoria quartzite on the east side, and of a rhyolite porphyry on the west slope of the range. The aggregate thickness of the Lanoria quartzite and the rhyolite porphyry approximates 3,600 feet (Fig. 2). At Silver City and in the Oscura Mountains the basement rocks are pre-Cambrian granites (Figs. 2 and 3). Pre-Cambrian gneiss and schist crop out near Kingston, New Mexico, on the eastern slope of the Black Range. Similar gneisses and schists are present on the western slopes of the Sierra Caballos. The pre-Cambrian rocks of the Organ Mountains range from granites and schists in the southern part to granites in the northern part of the range, whereas the basement of the San Andres Range is pre-Cambrian granite.

PALEOZOIC

CAMBRIAN[4]

The oldest known Paleozoic formation in the region is the Bliss sandstone of Upper Cambrian age, the type locality of which is in

[4] The assignment of the Bliss sandstone to the Cambrian, although it follows previous literature, does not agree with the most recent interpretation by Josiah Bridge and Philip B. King of the United States Geological Survey. King, in the preceding paper of the present symposium, assigns the Bliss sandstone to the Lower Ordovician (lower Beekmantown) and restricts the term *Van Horn* to an underlying sandstone of pre-Cambrian or Cambrian age. The Van Horn (restricted) is presumably absent in the Franklin Mountains, where, according to Bridge, Lower Ordovician Bliss rests on the pre-Cambrian.—Editorial note.

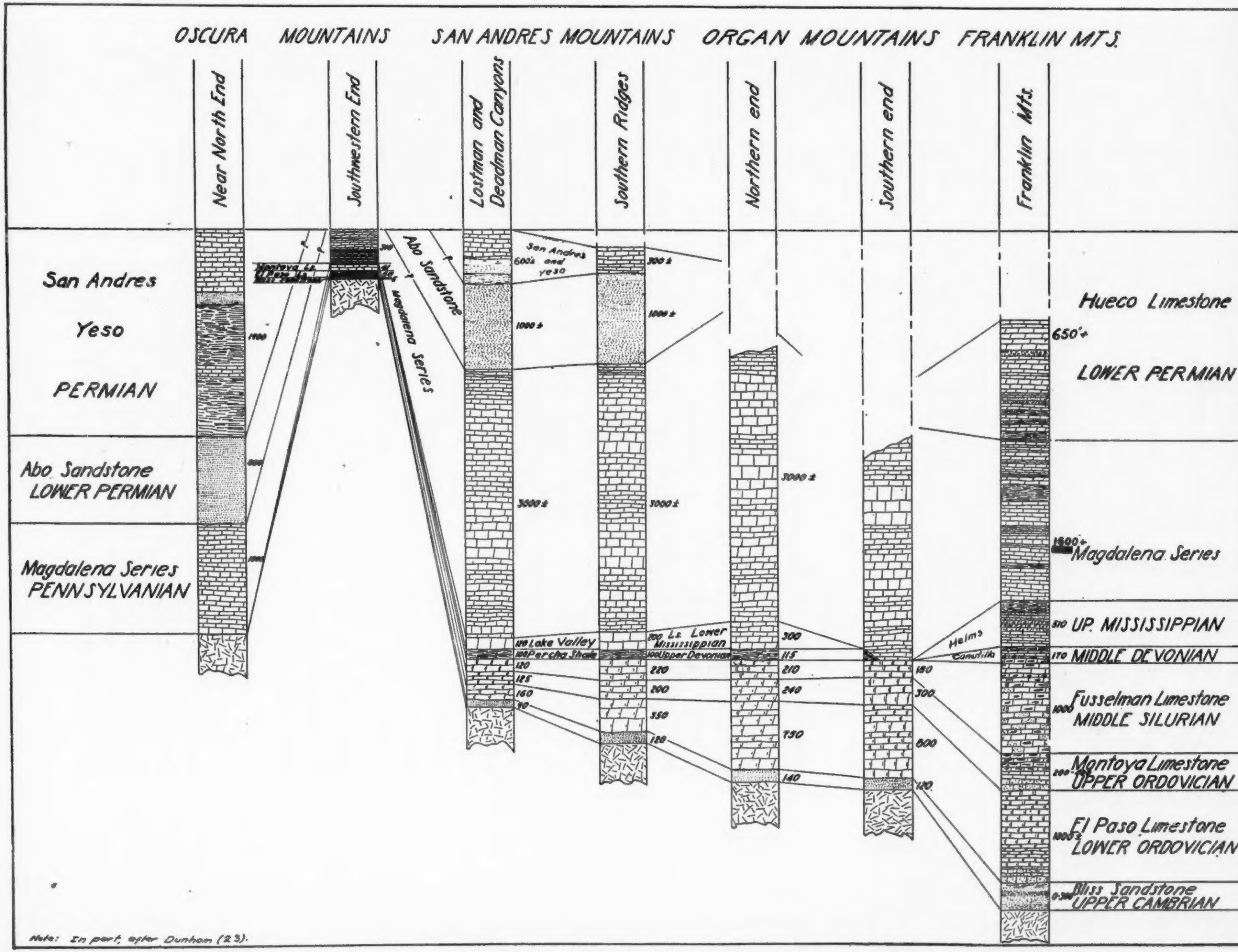

FIG. 2.—Correlation of sediments between Silver City, New Mexico, and El Paso, Texas.

the Franklin Mountains (1). At Van Horn (2) its equivalent is the Van Horn sandstone which ranges in thickness from a thin film to 300 feet. At Silver City, New Mexico (3), it has a maximum thickness of 200 feet. In the northern end of the Oscura Mountains it is absent, but in the southern end it is represented by a few feet of sandstone and gradually thickens from there southward.

ORDOVICIAN

The El Paso limestone is an important stratigraphic unit in the southwest. It crops out in the Van Horn Quadrangle and ranges in thickness from a thin film to 1,000 feet. In the region of this report its eastern outcrop is in the Hueco-Sacramento Mountains; its northern exposure is in the southern end of the Oscura Mountains; and its western limit probably is the same as that of the underlying Bliss. The type section of this limestone is in the Franklin Mountains, where it has a thickness of approximately 1,000 feet. Its few fossils are found within a hundred feet of the base (in the Franklin Mountains) and are regarded as Lower Ordovician. Everywhere the El Paso limestone is fairly persistent and maintains a thickness of 500–1,000 feet, except along its northern boundary where it is about 60 feet thick. It also thins toward the western boundary.

The Montoya limestone, Upper Ordovician in age, is likewise well represented in this district. Its thickness averages between 250 and 400 feet throughout the entire area, excepting near its northern limit in the southern part of the Oscura Mountains, where its thickness decreases to a few feet (Fig. 3). In the Franklin Mountains the formation is in contact with the underlying El Paso limestone, and nowhere within these mountains is there recorded the equivalent of the Simpson (Middle Ordovician) group. The closest northern occurrence of Middle Ordovician sediments is the Harding of southern Colorado. The type section of the Montoya is in the Franklin Mountains; here it contains a distinctive Richmond fauna which distinguishes it from the underlying El Paso limestone. The contact, in the Franklin Mountains, can best be seen on Scenic Point about one mile north of the city of El Paso.

SILURIAN

The Fusselman limestone, a massive dolomitic limestone of Middle Silurian age, crops out on some of the highest summits of the Franklin Mountains. This limestone also occurs almost everywhere in the district, but is extremely variable in thickness. Its greatest thickness is recorded in the Franklin Mountains. In the Oscura Mountains it is entirely absent while in the Van Horn district it has

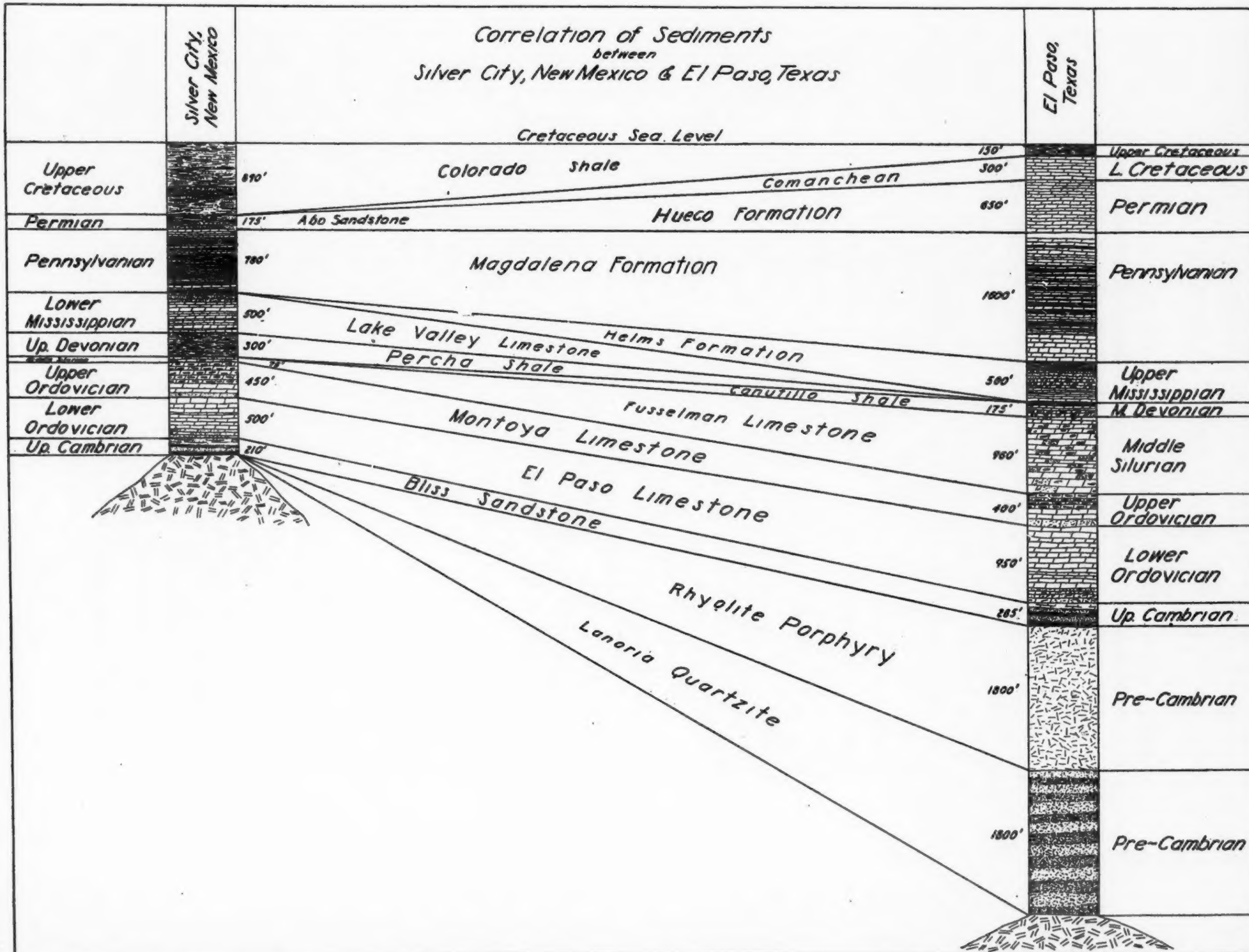

FIG. 3.—Correlation of sediments between northern end of Oscura Mountains and southern end of Franklin Mountains.

recently been reported as possibly being present (29). It does not exceed 100 feet in thickness in the region near Silver City. The Fusselman carries a characteristic Niagaran (Middle Silurian) fauna.

The formation forms the dip slope of the higher portion of the Franklin Mountains opposite Vinton, Texas, and is overlain by either the Middle Devonian sediments or, in places, by the Magdalena.

DEVONIAN

No lower Devonian sediments have been reported in the entire district, but the Middle Devonian is represented in the Franklin Mountains by about 175 feet of sediments consisting of: cherty limestone, light brown in color, immediately overlying the Fusselman; a thin bed of fossiliferous gray limestone; a thin bed of dense, almost black sandstone, which weathers brown; and about 40 feet of black, fissile shale occurring at the top of the formation. Darton (4) and others reported this as Upper Devonian (Percha) in age, but Kirk[5] identified it as Middle Devonian. This equivalent probably occurs in the Hueco Mountains but it does not crop out beyond the northern end of the Franklin Mountains or in the western part of the area. Since this formation was at first thought to be the Percha equivalent and later was classified as Middle Devonian with no formational name given to it, the writer has proposed that it be called the Canutillo formation (32). The formation takes its name from the town of Canutillo, Texas, on the Santa Fe Railroad about 13 miles north of El Paso.

The Upper Devonian (Figs. 2 and 3) is represented in the western part of the district by the Percha shale, which undoubtedly represents an invasion of the sea equivalent to that of the Ouray of southwestern Colorado. The formation is well exposed in the regions of Silver City, Santa Rita, Georgetown, and the Black Range (Lake Valley, Hillsboro, Kingston), Caballo Mountains and San Andres Mountains. These localities are all in southwestern New Mexico and, as far as known, the formation does not occur within the state of Texas. It has been reported from the Sacramento Mountains (17), opposite Alamogordo, New Mexico, but Stainbrook (31) states that this outcrop has a "close relationship to the Independence shale of Iowa rather than the nearer Percha shale." The Percha shale has an average thickness of 250 feet. Its southern limit is about 2 miles north of Organ Pass.

[5] Personal communication from Dr. Girty.

MISSISSIPPIAN

The Lake Valley limestone of Kinderhook-Osage age (8) covers the same areas as the Percha, but overlaps it slightly toward the north, and overlaps the Devonian at least as far east as the Sacramento Mountains. Near Silver City the thickness of the Lake Valley approximates 500 feet; it thins northeast, south, and east. Its northern limit approaches Latitude 34° North. The Lake Valley limestone (7) has not been positively identified in the Franklin Mountains or the Hueco Mountains, although King (11) has suggested the possibility of its presence in these mountains.

The Helms formation was first defined by Beede (10) in 1918 from the Hueco Mountains where it has a thickness of about 500 feet and consists mostly of limestones and sandstones. In 1934 King (11) reported this formation from the Franklin Mountains where it is composed mostly of thin-bedded, dark-colored limestone with an upper member of shale. The thickness in the Franklin Mountains is approximately 500 feet. The Helms formation has been reported only from West Texas and, so far as known, does not crop out in New Mexico. The Helms contains a distinctive Chester fauna[6] which distinguishes it from the overlying Magdalena formation.

PENNSYLVANIAN

General.—The name Hueco was first introduced by Richardson (1) in 1909 to include the Upper Carboniferous or Pennsylvanian and Permian series of trans-Pecos Texas. Since that time it has been shown that the Hueco limestone included about 175 feet of Middle Devonian sediments at the base and about 500 feet of limestone and shale now known to be Upper Mississippian (Helms) in age. There is a probability that most of the Hueco limestone of the Hueco Mountains is Permian in age and that only a small part of the Hueco, as originally defined, is Pennsylvanian. The correct name for the Pennsylvanian, in this district, therefore, would seem to be Magdalena, since this name applies to the Pennsylvanian sediments in the neighboring vicinities in New Mexico.

Magdalena formation.—The name Magdalena was taken from the Magdalena Mountains in Socorro County, New Mexico, and was proposed by Gordon (13) in 1907, to include a series of limestone, shale, and sandstone beds occurring in the Rio Grande Valley of New Mexico. Since the Magdalena is so well established in the near-by regions of New Mexico and since correlation of the beds in the Frank-

[6] G. H. Girty, personal communication.

lin Mountains with those of north-central Texas is difficult, it was decided to adopt the name Magdalena for the Pennsylvanian of the Franklin Mountains.

The Magdalena at Silver City unconformably overlies the Lake Valley limestone, although the beds above and below the break appear to lie in parallel position. It is divided into two formations: the lower, the Oswaldo (24), about 400 feet thick, is composed principally of limestone and shale; the upper, the Syrena, about 400 feet thick, is composed of shale at the base and limestone with thin partings of shale above.

In the northern end of the Oscura Mountains the Magdalena rests on the pre-Cambrian granite and is about 1,000 feet thick. Northward to the Taos region the Magdalena increases in thickness to about 3,000 feet (12). Southward from the Oscura Mountains, in the regions of the San Andres and the Organ mountains, the Magdalena also has a thickness of about 3,000 feet maximum (23), and is composed almost entirely of limestone. In the San Andres Mountains and in the northern end of the Organ Mountains the Magdalena overlies the Lake Valley limestone (Fig. 3), but in the southern end of the Organ Mountains it apparently overlies the Fusselman limestone. In the Sacramento Mountains the Magdalena also overlies the Lake Valley limestone, while in the Hueco and Franklin mountains it is disconformable above the Helms. From a study of the list of fossils collected from the Hueco of Richardson of the Van Horn region (2), the impression is gained that the Magdalena equivalent of the Franklin Mountains is apparently absent in that area.

The Magdalena of the Franklin Mountains consists of about 1,600 feet or more of thin-bedded, dark gray to black limestone with a few partings of shale. Some cherty limestone is present in the lower members. Near the middle and also near the top of the exposed section thin beds of conglomerate appear. Two thin beds of sandstone aggregating not more than 10 feet are present. Between the exposed top of the formation and the base of the exposed Hueco (Permian) a thickness of approximately 1,800 feet of sediments, probably Pennsylvanian in age, are buried below alluvium.

A stratigraphic column of the Magdalena sediments, measured opposite Vinton, Texas, is shown in Figure 4, and a sketch showing the relief and the attitude of the Magdalena formation with respect to the immediately underlying sediments is shown in Figure 5.

The stratigraphic members employed for the sake of convenience, beginning with the uppermost, are: Bishop's Cap (named for Bishop's Cap Peak about opposite Filmore, New Mexico), which includes

measured bed numbers 100 to 127; the Berino member (named from Berino, New Mexico, a town on the Santa Fe Railroad about 4 miles north of the Texas-New Mexico boundary), beds 46 to 99b; and the La Tuna member (named for the town of La Tuna, Texas, on the Santa Fe Railroad at the Texas-New Mexico boundary), including beds from the base of the Magdalena section to bed 45.

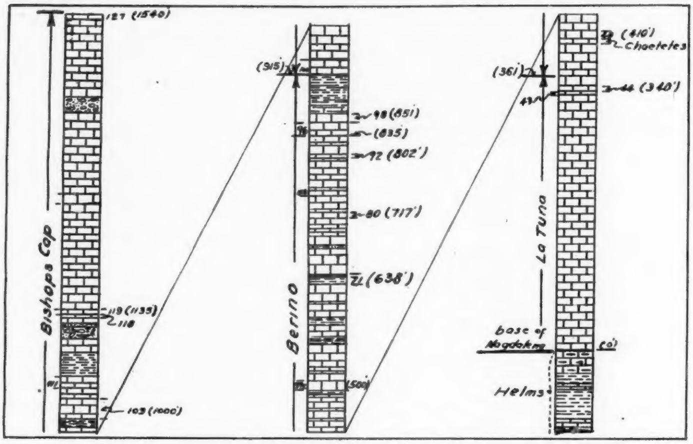

FIG. 4.—Columnar section of Magdalena sediments. Numbers in parentheses indicate distance above base; other numbers relate beds. Vertical scale: 1 inch equals approximately 200 feet.

DETAILED SECTION OF MAGDALENA FORMATION

BISHOP'S CAP MEMBER

Top of expo ed Magdalena section

Bed No.	*Description of Sediments*	*Thickness in Feet*
127	Black, fine-grained limestone	115
126	Chert conglomerate	20
125	Gray, coarse-grained limestone	52
124	Yellow to brown, fine-grained limestone	30
123	Dark, fine-grained limestone	21
122	Dark to black, fine-grained limestone, containing: *Linoproductus prattenianus; Spirifer triplicatus; Marginifera lasallensis; Composita subtilita*	12
121	Fine-grained, light to dark gray limestone	98
120	Fine-grained, light to dark gray limestone, containing: *Trepospira depressa; Patellostium montfortianum; Bellerophon crassus; Euphemus carbonarius; Bucanopsis meekiana; Pharkidonotus percarinatus; Nuculposis ventricosa; Composita subtilita*	44
119	Fine-grained, light to dark gray limestone, containing: *Fusulina euryteines; Michelinia eugenae; Wewokella solida; Mesolobus decipiens; Marginifera splendens; Spirifer triplicatus; Ambocoelia planoconvexa; Nuculopsis ventricosa; Astartella concentrica; Pleurotomaria*	

	carbonaria; Soleniscus (Macrochilina) intercalaris; Patellostium montfortianum; Euphemus carbonarius; Bucanopsis meekiana; Pharkidonotus percarinatus; Trepospira depressa	7
118	Fine-grained, light to dark gray limestone, containing: *Michelinia eugenae; Productus inflatus?; Linoproductus prattenianus; Cleiothyridina orbicularis; Composita subtilita; Leda bellistriata*	5
117	Dense, fine-grained, dark limestone	8
116	Sandstone	2
115		
114	Limestone conglomerate	18
113	Coarse, gray, crystalline limestone	19
112	Fill, probably shale	30
111	Fine-grained black limestone, weathers gray, containing: *Dictyoclostus portlockianus; Cleiothyridina orbicularis; Composita subtilita; Leda bellistriata; Patellostium montfortianum; Bellerophon crassus; Pharkidonotus percarinatus*	13
110	Black crystalline limestone, weathers brown	16
109	Coarse, buff, crystalline limestone, weathers gray, containing: *Mesolobus decipiens; Ambocoelia planoconvexa; Leda arata; Astartella concentrica; Nuculopsis ventricosa; Pseudozygopleura (Pseudozygopleura) multicostata; Trepospira depressa; Soleniscus (Macrochilina) brevis; Patellostium montfortianum; Bellerophon crassus; Euphemus carbonarius; Pharkidonotus percarinatus*	24
108b	Fill, probably shale	11
108a	Coarse, gray, crystalline limestone, weathers brown	9
107	Gray, crystalline limestone, weathers light gray	25
106	Sandstone	3
105	Conglomerate	3
104		
100	Coarse, gray limestone, bottom of bed 100 contains: *Spirifer triplicatus; Naticopsis ventricosa; Soleniscus (Macrochilina) regularis; Euphemus inspeciosus; Pseudorthoceras knoxense?*	34

BERINO MEMBER

99b	Fill, probably shale	45
99a	Gray limestone, weathers mottled	8
98	Limestone, weathers brown to black, contains: *Fusulina euryteines; Chonetes flemingi?; Marginifera wabashensis; Pseudozygopleura (Pseudozygopleura) scitula; Orthonema salteri; Orthonychia parva; Euconispira bicarinata; Bellerophon crassus*	11
97	Almost black limestone, weathers gray	2
96	Dark, fine-grained limestone, weathers gray and tan; bottom of bed marly and contains: *Spirifer rockymontanus; Spirifer triplicatus; Spiriferina kentuckyensis; Astartella varica; Taosia copei; Helminthozyga (Hemizyga) grandicostata; Donaldina stevensana; Murchisonia quadricarinata; Goniospira lasallensis; Pleurotomaria granulostriata; P. scitula; P. spironema; Worthenia perizomata; Orthonema inornatum; O. sayrei; O. carbonaria; O. salteri; Soleniscus (Soleniscus) typicus; S. (Macrochilina) brevis; S. (M.) paludinaeformis; S. (M.) regularis; Meekospira peracuta; Microdoma conicum; Anomphalus rotulus; Naticopsis meeki; N. ventricosa; Trachydomia whitei; Straparollus (Euomphalus) reedsi; Bellerophon crassus; Pharkidonotus percarinatus;* and many new species of Pseudozygopleuroid gastropods	14
95	Fine-grained, gray limestone, weathers gray	10
94	Fine-grained, black limestone, weathers gray and brown	4
93	Dark gray limestone, with brown nodules, weathers gray	10
92	Dense, fine-grained black limestone; top weathers yellow; middle of bed weathers gray, contains: *Dictyoclostus portlockianus; Spirifer rockymontanus; Leda bellistriata; Astartella concentrica; Myalina orthonota; Worthenia tabulata; Angyomphalus moniliferus; Bellerophon crassus; Bucanopsis meekiana*	9

91	Grayish black limestone, weathers light gray	4
90	Fine-grained limestone, weathers brown and gray	9
89	Coarse-grained, gray limestone, weathers light gray	9
88	Fine-grained, dark gray limestone, weathers gray	5
87	Coarse-grained, crinoidal limestone	6
86	Dense, fine-grained, brown limestone, weathers light gray, capped with 2 feet of chert	5
85		
84	Fine-grained, black limestone, containing: *Zaphrentis gibsoni?; Dictyoclostus portlockianus; Pustula nebrascensis; Composita subtilita.*	6
83	Semi-coarse, gray limestone	9
82	Fine-grained limestone	8
81	Dense, fine-grained, brown limestone	3
80		
78	Fine-grained, dark to black limestone, containing: *Derbya crassa; Productus hermosanus; Marginifera muricata; M. splendens; Spirifer occidentalis; S. triplicatus; Squamularia perplexa; Cleiothyridina orbicularis; Enteletes hemiplicatus?; Bellerophon crassus; Bucanopsis meekiana; Straparollus* (*Euomphalus*) *reedsi*	21
77	Brownish limestone, weathers reddish brown	6
76	Fine-grained, black limestone, weathers gray and brown	10
75	Grayish black limestone, weathers tan and gray	11
74	Conglomeratic limestone?	4
73	Fine-grained, siliceous limestone, weathers yellowish brown, containing: *Taosia copei; Goniospira lasallensis; Orestes nodosus; Soleniscus* (*Soleniscus*) *typicus; S.* (*Macrochilinia*) *brevis; S.* (*M.*) *regularis; Meekospira peracuta; Patellostium montfortianum; Euphemus inspeciosus; Bucanopsis meekiana; Pharkidonotus percarinatus;* and many new species of *Pseudozygopleura; Paleostylus; Murchisonia* and *Orthonema*	23
72	Massive, black limestone, weathers gray	13
71	Fine-grained limestone, weathers gray and tan, with some shale, containing: *Productus hermosanus; Rhipidomella carbonaria; Mesolobus decipiens; Linoproductus prattenianus; Marginifera missouriensis?; M. splendens; Spirifer opimus; Squamularia perplexa; Edmondia aspinwallensis; Parallelodon sangamonensis; Nuculopsis ventricosa; Astartella compacta; Dentalium* sp.; *Plagioglypta* sp.; *Bellerophon majusculus; Pharkidonotus percarinatus; Worthenia tabulata; W. perizomata; Pseudozygopleura* (*Stephanozyga*) *nodosa; Taosia copei; Pleurotomaria scitula; Trepospira depressa; Orthonema inornatum; Soleniscus* (*Macrochilina*) *regularis; Angyomphalus minutus; Naticopsis ventricosa; N. scintilla; N. meeki; Trachydomia whitei; Orthonychia parva; Ianthinopsis gouldiana; Patellostium montfortianum; Euphemus carbonarius; E. inspeciosus; Bucamopsis meekiana; Griffithides scitulus; Fusulina euryteines*	12
70	Limestone conglomerate within bed 71	3
69	Semi-coarse, gray to black limestone	20
68	Brownish limestone, weathers buff	3
67	Fine-grained, light to dark gray limestone	16
66	Fill, probably shale	10
65	Fine-grained, light to dark gray limestone	13
64b	Fill, probably shale	11
64a	Fine-grained, light to dark gray limestone	20
63	Dense, fine-grained, black limestone, weathers light brown, buff to yellow	15
62	Fine-grained, light to dark gray limestone	3
61	Dense, fine-grained, black limestone, weathers gray	10
60	Fill, probably shale	5
59x	Fine-grained, light to dark gray limestone, weathers gray, contains: *Chonetes flemingi?; Productus gallatinensis; Spirifer rockymontanus; Euphemus nodocarinatus; Derbya?* sp.	15
59	Dense, fine-grained, black limestone	2
58		

57	Coarse-grained, crystalline limestone	7
56	Fine-grained, light to dark gray limestone	9
55	Coarse-grained, crystalline limestone	3
54		
53	Fine-grained, light to dark gray limestone	11
52	Fine-grained, brown limestone	3
51	Fine-grained, light to dark gray limestone	18
50		
49	Dense, fine-grained, black limestone, weathers brown	22
48	Fine-grained, light to dark gray limestone, containing: abundant *Chaetetes milleporaceous*	10
47	Dense, fine-grained, black limestone, weathers light gray, contains: *Productus gallatinensis; Linoproductus prattenianus; Spirifer rockymontanus; Rhipidomella carbonaria; Composita subtilita*	7
46	Massive, pitted, cherty layers near top and some cherty layers within the bed of light to dark gray limestone	42
	LA TUNA MEMBER	
45	Thin-layered, light to dark gray limestone with layers of chert, containing: *Petalodus destructor*	10
44	Massive, pitted, dark gray limestone, weathers gray and contains: *Rhombopora lepidodendroidea; Fistulipora* aff. *F. zonata; Eupachycrinus*? sp.; *Rhipidomella carbonaria; Chonetes flemingi; Marginifera missouriensis; M. splendens; Productus gallatinensis; Linoproductus prattenianus; Spirifer rockymontanus; Spiriferina kentuckyensis; Hustedia mormoni; Squamularia perplexa; Cancrinella boonensis; Rhynchopora carbonaria; Cleiothyridina orbicularis; Composita subtilita; Leda bellistriata; Astartella varica; Naticopsis meeki; Orthonychia parva; Straparollus (Euomphalus) reedsi*	11
43	Base massive, semi-coarse-grained, light to dark gray limestone forming scarp above top of Helms shale	340
	Total	1,534

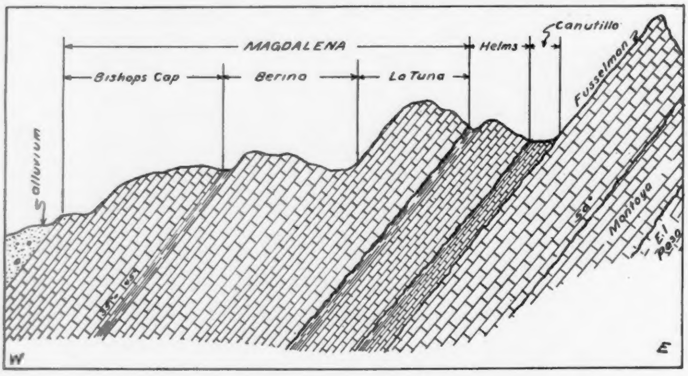

FIG. 5.—Sketch showing relation of Magdelena to underlying sediments.

From this description of sediments it will be noted that a large percentage of the fossils listed belong to the class Gastropoda. Few gastropod fossils similar to those of the Magdalena have been reported from the Pennsylvanian of the other parts of the region under dis-

cussion. A few closely allied species have been reported by White (12) from the Taos region of northern New Mexico. Johnson (22) lists a number of genera and species of gastropods from the Mosquito Range of Colorado. However, the most striking similarity to the Magdalena gastropods from the Franklin Mountains is to the faunas described by Knight (30) from the St. Louis outlier (lower Pennsylvanian) of Missouri, and from its equivalent horizon (St. David's limestone) of Illinois. A large collection of brachiopod fauna has been completed, but the material has, as yet, not been classified. Hence the lack of information pertaining to the brachiopods, as well as to other phyla is noticeable in the tabulation of sediments for the Magdalena. The exposed top of the Magdalena, according to J. W. Skinner,[7] is middle Strawn in age, as evidenced by the *Fusulina euryteines* Thompson. These, as will be noted from the tabulation, occur for the last time in bed number 119.

PERMIAN

In the Silver City-Santa Rita district the Permian is represented by the Abo sandstone, which overlies the Magdalena and ranges from a thin film to a bed 200 feet thick. In the Oscura Mountains the Permian is represented by the Abo sandstone below and the Yeso and San Andres above. The combined thickness of these sediments in the Oscura Mountains is about 2,700 feet. The combined thickness of these sediments decreases to about 1,300 feet in the San Andres Mountains.

The Permian is represented in the Franklin Mountains by about 650 feet of exposed sediments known as the Hueco. These sediments occur as outliers about $\frac{1}{4}$ mile west of the Franklin Range and are separated from the exposed Magdalena sediments by alluvial deposits; hence, the contact between the Magdalena and the Permian has not been seen. The sediments are principally fine-grained, dense, light-colored limestones. Dunbar and Skinner (25) have reported characteristic Fusulinidae from the Hueco limestone of the Franklin Mountains.

The Hueco sediments of the Hueco Mountains and also in the Van Horn district are too well known to need comment or discussion in this report. For information relative to these regions, refer to the many publications by Philip B. King.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 1 (JANUARY, 1940), PP. 173-179 1 FIG.

CORRELATION OF PENNSYLVANIAN ROCKS OF NEW MEXICO[1]

C. E. NEEDHAM[2]
Socorro, New Mexico

ABSTRACT

A typical section of Pennsylvanian rocks in central New Mexico is 1,500–1,800 feet thick. The lowest beds lie below the zone of *Fusulina* and contain *Chaetetes milleporaceous, Spirifer rockymontanus, Spirifer occidentalis, Cleiothyridina orbicularis*, and *Mesolobus mesolobus*. These beds are considered to be younger than Bend, Morrow, or lower Pottsville, and are believed to be correlative with the lower Cherokee, lower Atoka, upper Dornick Hills, lower Deese, lower Millsap Lake, lower Hartville, upper Pottsville, and lower Allegheny.

The zone above this contains *Fusulina euryteines, Wedekindellina euthysepta, W. excentrica, Chaetetes milleporaceous, Cleiothyrodina orbicularis*, and *Mesolobus mesolobus*. These beds are correlated with the upper Cherokee, McCoy, upper Hermosa, middle Hartville, upper Millsap Lake, Haymond, upper Atoka, middle Deese, Boggy, Wetumka, Carbondale, and upper Allegheny. The equivalent of the Marmaton and Wewoka has not been recognized but is believed to be present.

The succeeding zone is the equivalent of the Kansas City and Lansing, upper Hartville, middle Gaptank, middle Canyon, middle Hoxbar, and lower Conemaugh. It is characterized by *Triticites nebraskensis, Echinoconchus semipunctatus*, and *Neospirifer latus*.

Next above is a zone containing numerous advanced species of *Triticites, Enteletes hemiplicatus, Marginifera hystricula*, and *Chonetes transversalis*. This zone is the equivalent of the lower Virgil, lower Cisco, upper Gaptank, and Vamoosa. Finally, the highest beds contain *Triticites ventricosus* and are probably the equivalent of a part of the Wabaunsee and the upper part of the Cisco (restricted).

All the rocks of Pennsylvanian age in New Mexico are known as the Magdalena formation from the Magdalena Mountains in Socorro County. To the present time this formation has not been subdivided into smaller units that can be recognized in other areas. Careful and detailed work will undoubtedly show that smaller units can be recognized in different areas, but it is impossible to subdivide these rocks as they have been done in the Mid-Continent and Mississippi-Ohio valley regions.

A typical section of the Magdalena formation near Socorro consists of 1,500–1,800 feet of sediments divisible into two lithological types. The lower is 600–700 feet thick and consists mainly of sandstones, shales, and a few thin limestones; the upper type is 800–1,000

[1] Read before the Association at El Paso, Texas, September 29, 1938. Manuscript received, July 27, 1939.

Needham's paper was completed several months ahead of Cheney's "Geology of North-Central Texas," which is also in this symposium. Necessarily, therefore, Needham in his text and figures follows the scheme of nomenclature for the Pennsylvanian rocks of north-central Texas set forth in E. H. Sellards *et al.*, "The Geology of Texas. Vol. 1. Stratigraphy," *Univ. of Texas Bull. 3232* (1932). Cheney proposes fundamental changes in this scheme. The relation between Cheney's and Sellards' classifications may be readily seen in Cheney's Figure 1 on page 66.—Editorial note.

[2] President, New Mexico School of Mines, director, State Bureau of Mines and Mineral Resources.

feet thick and consists largely of limestone, with some shale and numerous interbedded coarse sandstones.

It is not known to what extent the Pennsylvanian unconformities of the northern Mid-Continent are present in New Mexico, if they are present at all. The Pennsylvanian sediments in central New Mexico are probably mainly marine in origin; therefore, they differ in many respects from the sediments of the same age in Kansas,

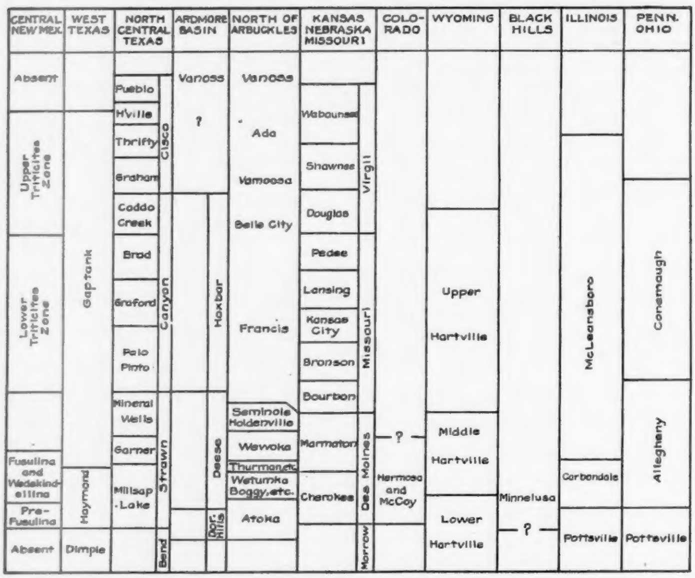

FIG. 1.—Correlation of Pennsylvanian rocks of New Mexico.

Missouri, and Illinois, where alternating beds of marine and continental origin are typically developed.

In correlating the Pennsylvanian beds of New Mexico with those of other regions, many of which are remote, chief reliance must be placed on fossil forms. In using these forms we must bear in mind that some of the species in New Mexico may have appeared or disappeared somewhat earlier or later than they did in other regions. Hence the correlation at this time is general or approximate in certain respects, yet when a number of forms are used it is considered that a fairly high degree of accuracy in correlation is possible.

TABLE I

DISTRIBUTION OF SOME PENNSYLVANIAN FOSSILS

	New Mexico				*West Texas*		*North-Central Texas*										*Ardmore Basin*		
	Pre-Fusulina	*Wedekindellina Fusulina*	*L. Triticites*	*U. Triticites*	*Haymond*	*Gaptank*	*Millsap Lake*	*Garner*	*Mineral Wells*	*Palo Pinto*	*Graford*	*Brad*	*Caddo Creek*	*Graham*	*Thrifty*	*Harpersville*	*Dornick Hills—Upper*	*Deese*	*Hoxbar*
Spirifer rockymontanus	x						x		x								x	x	
Spirifer occidentalis	x																		
Spirifer opimus		x																	
Chaetetes milleporaceous	x	x				xL											x		
Cleiothyridina orbicularis	x	x																	
Dictyoclostus portlockianus	x	x	x	x															
Mesolobus mesolobus		x							x								x	x	
Enteletes hemiplicatus				x											x	x			
Neospirifer triplicatus	x	x	x	x															
Neospirifer latus			x																
Composita elongata			x	x															
Marginifera hystricula				x															
Chonetes transversalis				x											x	x			
Dictyoclostus crassicostatus				x															
Echinoconchus semipunctatus			x																
Echinoconchus semipunctatus var. *knighti*		x																	
Fusulinella																			
Fusulina		x			x	xL	x												
Wedekindellina		x				xL	x												
Triticites			x	x		x			x	x	x		x	x	x	x			
Fusilina euryteines		x			x		x												
Wedekindellina euthysepta		x					x												
Wedekindellina excentrica		x																	
Triticites nebraskensis			x																
Triticites ventricosus				x											x	x			

	North of Arbuckles							*Northern Mid-Continent*											*Ohio Penn.*				*Wyoming*			*Colo.*		*Black Hills*	*Illinois*		
	L. Atoka	*U. Atoka*	*McAlester*	*Savannah*	*Boggy*	*Wetumka*	*Wewoka*	*L. Cherokee*	*U. Cherokee*	*Marmaton*	*Bourbon*	*Bronson*	*Kansas City*	*Lansing*	*Pedee*	*Douglas*	*Shawnee*	*Wabaunsee*	*L. Pottsville*	*U. Pottsville*	*Allegheny*	*Conemaugh*	*L. Hartville*	*M. Hartville*	*U. Hartville*	*Hermosa*	*McCoy*	*Minnelusa*	*Pottsville*	*Carbondale*	*McLeansboro*
Spirifer rockymontanus								x												x											
Spirifer occidentalis								x												x											
Spirifer opimus									x											x											
Chaetetes milleporaceous									x	x																					
Cleiothyridina orbicularis										x			x																		
Dictyoclostus portlockianus									x	x			x	x																	
Mesolobus mesolobus									x	x																					
Enteletes hemiplicatus																xU	x	x													
Neospirifer triplicatus										x			x	x		x	x	x													
Neospirifer latus													x	x																	
Composita elongata													x	x		x															
Marginifera hystricula																	x	x													
Chonetes transversalis																xU	x	x													
Dictyoclostus crassicostatus													x	x		x	x														
Echinoconchus semipunctatus													x	x		x															
Echinoconchus semipunctatus var. *knighti*										x																					
Fusulinella	x	x			x			x												x	x		x					x	x		
Fusulina					x	x		x	x	x														x		x				x	xL
Wedekindellina		x						x	x															x						x	
Triticites													x	x		x	x	x				x			x						x
Fusilina euryteines						x			x															x		x					
Wedekindellina euthysepta		x			x				x																					x	
Wedekindellina excentrica																								x		x	x				
Triticites nebraskensis													x	x		x	x														
Triticites ventricosus																	x	x													

U=Upper
M=Middle
L=Lower

In the preparation of this paper the writer, of necessity, has drawn heavily on the publications of other workers. The publications found especially helpful are listed in the included bibliography.

The fauna of the New Mexico Pennsylvanian is large and fairly well preserved but has been very little studied. It includes numerous fusulinids, brachiopods, bryozoans, a few corals, an occasional crinoid calyx, and in a few places many gastropods and pelecypods; cephalopods are so rare as almost to be curiosities; trilobites are also rare. The ranges are known for only a few of the numerous species.

No attempt is made to correlate beds in New Mexico with the numerous members and thin formations of the Mid-Continent region. Rather, the correlation is largely confined to groups and series and to the larger formational units (Fig. 1).

In June, 1937, the writer published a short report on some of the fusulinids found in New Mexico and used them as a basis for regional correlation. More recently some of the other forms, particularly the brachiopods, have been studied, and it is found that a number of them are identical with forms described from other regions and are sufficiently restricted in vertical range to serve in long-distance correlation. This is especially true when they are used in conjunction with the fusulinids.

The writer has previously shown that the lowest part of the Pennsylvanian in New Mexico, up to a thickness of 700 feet in some places, apparently contains no fusulinids. This portion lies below the zone of *Wedekindellina* and *Fusulina* and should contain *Fusulinella*,[3] which genus, however, has not been reported from this state. The fauna in this zone is marked by the occurrence of such distinctive forms as the coral, *Chaetetes milleporaceous*, and the brachiopods, *Spirifer rockymontanus*, *S. occidentalis*, *Mesolobus mesolobus*, and *Cleiothyridina orbicularis*. *Spirifer rockymontanus*, *S. occidentalis*, and *Chaetetes milleporaceous* are reported from beds of Bend or Morrow age; the others are not. Other distinctive Bend or Morrow forms have not been reported from this zone. Therefore, equivalents of the Bend, Morrow, or lower Pottsville may be present in the extreme lower part of the Magdalena, but it is possible that they are lacking. On the other hand, the forms listed are characteristic of the Des Moines series and its equivalents. *Spirifer rockymontanus* is present in the Dornick Hills formation of the Ardmore basin and the Pottsville of Illinois and Ohio. *S. occidentalis* is found in the Pottsville of Ohio

[3] In December, 1939, M. L. Thompson and the writer discovered the zone of *Fusulinella* near Hot Springs, New Mexico.

and in the base of the Cherokee in central eastern Oklahoma but is rare in Kansas and Missouri. It is believed, therefore, that a considerable part of the Magdalena below the zone of *Wedekindellina* and *Fusulina* is correlative with the lower Cherokee, some part of the Minnelusa, the upper Pottsville and lower Allegheny, some part of the lower Atoka, the upper part of the Dornick Hills and lower Deese, the lower Millsap Lake, the lower Hartville, and possibly the lower part of the Hermosa.

In New Mexico, *Mesolobus mesolobus*, *Cleiothyridina orbicularis*, and *Chaetetes milleporaceous* pass upward into the zone of *Wedekindellina* and *Fusulina*, as they do in several other regions. *Fusulina euryteines*, widespread in New Mexico, is found in the upper Cherokee, Hermosa, Millsap Lake, Haymond, middle Hartville, and Wetumka. *Wedekindellina euthysepta*, also common in New Mexico, occurs in the upper Cherokee, upper Atoka, Millsap Lake, upper Boggy, and the Carbondale. *W. excentrica*, present in New Mexico, is found in the McCoy, Hermosa, and middle Hartville. *Spirifer opimus*, associated with *Fusulina* in New Mexico, is reported from the Cherokee and upper Pottsville.

With the exception of *Cleiothyridina orbicularis*, which ranges up into the Kansas city group, none of the forms listed ranges past the Des Moines series. Equivalents of Des Moines beds, therefore, are easily recognized in New Mexico, as well as in many other parts of the United States.

Fusulinids of distinctive Marmaton age have not been reported from New Mexico. The writer has observed no stratigraphic evidence that this zone is absent; probably Marmaton fusulinids are lacking or have not been discovered.

The maximum thickness of Des Moines beds in central New Mexico is about 1,000 feet. In some places this thickness is reduced considerably because of wedging-out of sandstones interbedded with shales and limestones, and because of loss of the basal beds by lensing-out against topographic irregularities. Over a dome near Las Vegas the zone of *Fusulina* lies only a few feet above granite.

Beds of Kansas City and Lansing age in the Missouri series are marked in New Mexico by the occurrence of *Triticites nebraskensis*, *Neospirifer latus*, and *Echinoconchus semipunctatus*. It is probable that two new fusulinids, *Triticites wellsi* and *T. cuchilloensis*, described by the writer in an earlier paper, are also from beds of Missouri age. The beds containing this fauna are only a short distance above the zone of *Fusulina*. *Triticites nebraskensis* and *Echinoconchus semipunctatus*

are reported from the Douglas, as well as from the Kansas City and Lansing, but *Neospirifer latus* has been reported only from the Kansas City and Lansing.

Fossils diagnostic of Missouri age are not so plentiful and widespread as are Des Moines forms. Therefore, it is difficult to set the lower and upper limits of the Missouri equivalents. However, it appears likely that 350–400 feet is an average thickness for these beds in New Mexico.

The next succeeding beds contain numerous well developed species of *Triticites*, all of which are reported as yet only from New Mexico. However, their stage of development makes it appear rather certain that they are lower and middle Virgil in age, that is, Douglas and Shawnee. Associated with these are the brachiopods, *Enteletes hemiplicatus*, *Marginifera hystricula*, and *Chonetes transversalis*. These brachiopods are distinctive of the Virgil and lower Cisco series.

Among the forms found in the two afore-mentioned zones are others of longer range, yet of diagnostic value. Two of these that should be listed are *Composita elongata* and *Dictyoclostus crassicostatus*, both of which are confined to post-Cherokee beds in Nebraska.

Finally, the highest Pennsylvanian beds in New Mexico contain the robust complex fusulinid, *Triticites ventricosus*. Although this form has recently been reported from the Shawnee group, its greatest abundance and widespread occurrence are generally in beds of Wabaunsee age. Because of its distribution and because its greatest numbers lie above probable Shawnee fusulinids, it is considered to form a zone at least as young as lower Wabaunsee. This zone is best developed in the Sacramento Mountains, and it is believed that here are the youngest Pennsylvanian beds in New Mexico. It is probable that here too the Virgil equivalents reach their greatest thickness in the state, as much as 500 feet, or possibly more, being present. Elsewhere, these beds are thinner because of the unconformity in places at the base of the overlying Abo formation, which cuts out a part of the Pennsylvanian section.

In most places in the state the hiatus between the Pennsylvanian and Permian systems is known not to be great, inasmuch as robust species of *Triticites* are found at the top of the Pennsylvanian over a wide area. The writer hopes to discuss the question of the Pennsylvanian-Permian contact in New Mexico in a future paper.

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VOL. 24, NO. 1 (JANUARY, 1940), PP. 180-188, 3 FIGS.

UPPER PALEOZOIC SECTION OF CHINATI MOUNTAINS, PRESIDIO COUNTY, TEXAS[1]

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ABSTRACT

Previous work in the Chinati Mountains is briefly reviewed and the various exposures of Paleozoic sediments are described. The stratigraphy is discussed and evidence is presented demonstrating the presence of a Permian section nearly as complete as that of the Glass Mountains, as well as a fairly complete Pennsylvanian sequence.

INTRODUCTION

The present paper is in no wise intended to be a detailed study of the Chinati area, and the writer is fully cognizant of the fact that much information remains to be uncovered. Its purpose is to correlate the various upper Paleozoic beds with their equivalents in the Glass Mountain section, and it is hoped that these age determinations may be of some service to future workers.

Sediments of upper Paleozoic age are exposed in four comparatively large areas (Fig. 1) and at least two smaller outcrops in the Chinati Mountains of southwestern Presidio County. The principal exposures are in Pinto Canyon at the northwest end of the Chinati Mountains, in the hills west of the town of Shafter at the southeast end of the range, an area 3–8 miles north of Shafter and circling the west side of Sierra Alta, and a narrow band partially encircling the Ojo Bonito intrusive several miles northwest of Sierra Alta. These exposures are not connected, intervening areas being covered by alluvium and Tertiary lava flows. Furthermore, because of overlapping Comanche sediments and Tertiary lavas, no complete section is exposed in any single area.

The outcrops are located along the periphery of the Chinati uplift and the beds generally dip steeply away from the mountains. The section is locally complicated by intrusions and by faults of both the overthrust and normal types.

ACKNOWLEDGMENTS

The writer wishes to acknowledge his indebtedness to Weldon E. Cartwright, who first aroused his interest in the area and who visited several of the outcrops with him, and to V. C. Maley for valuable

[1] Read before the Association at El Paso, September 29, 1938. Manuscript received. December 29, 1939.

[2] Humble Oil and Refining Company.

advice and assistance both in the field and in the preparation of this paper.

PREVIOUS WORK

In 1904, J. A. Udden[3] described the Paleozoic sediments in the Shafter area and applied the name "Chinati series" to the entire

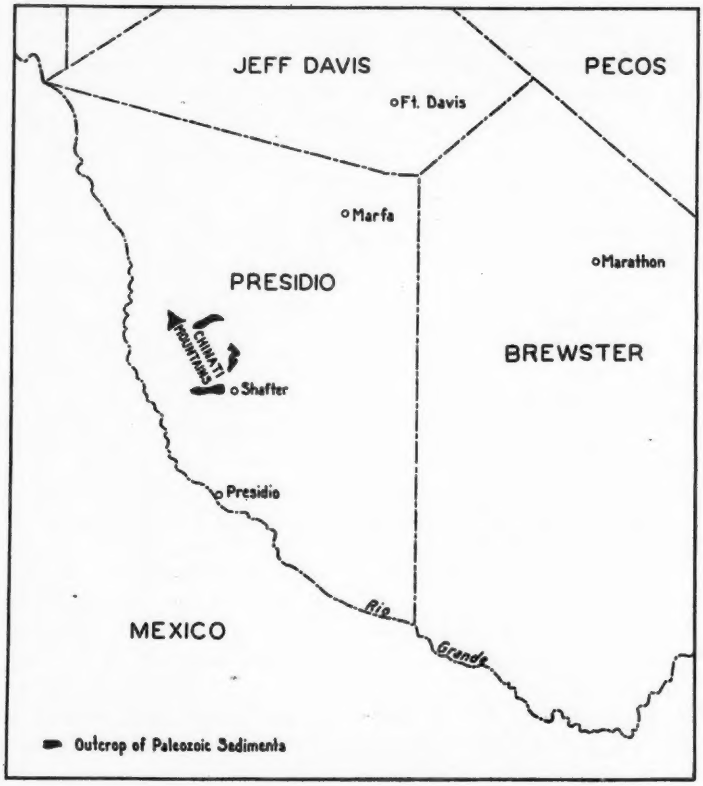

FIG. 1.—Sketch map showing location of principal exposures of Paleozoic rocks in Chinati Mountain area.

sequence. Although he apparently examined the exposures west of Shafter and near Ojo Bonito, his detailed descriptions are based on the section exposed north of Shafter in the vicinity of Sierra Alta.

[3] J. A. Udden, "The Geology of the Shafter Silver Mine District, Presidio County, Texas," *Univ. Texas Bull. 24* (1904).

Udden recognized three formational divisions within the Chinati series, and named these, in ascending order, Cieneguita, Alta, and Cibolo. The Cieneguita formation is typically exposed northwest of Sierra Alta and consists of approximately 1,000 feet of shale, sandstone, and limestone. Many of the sandstone and limestone beds are conglomeratic and contain small pebbles of clear quartz. As the base of the formation is not exposed, its total thickness cannot be determined.

At the southeast, apparently conformable on the Cieneguita, is the type section of the Alta formation, which is composed of two members. The lower consists predominantly of dark paper shale with many intercalated thin, hard sandstone layers. The upper member is composed principally of comparatively heavy beds of yellow to brown sandstone and yellow, sandy shale. The contact of these two members is gradational rather than sharp, and there is no physical evidence of a break at this point. The total thickness assigned to the Alta by Udden is 3,500 feet.

Udden's third formation, the Cibolo, overlies the Alta apparently conformably. In fact, the contact is a gradational one and the change consists chiefly of a gradual upward increase of limestone through about 100 feet of section. The Cibolo is overlapped by Comanche sediments, but at the type locality, in the bluffs east of the confluence of Cibolo and Sierra Alta creeks, Udden measured more than 1,400 feet of section. He divided the Cibolo into five members: the "transition beds" at the base, consisting of 100 feet of gray to yellow clay shale, yellow sandstone, and yellow sandy limestone; the "lower brecciated zone," described as 133 feet of massive, gray to brown, brecciated limestone; the "zone of sponge spicules" consisting of gray, tan, and brown siliceous limestone which locally contains abundant sponge spicules and which has a thickness of 85 feet; the "thin-bedded zone" composed of 470 feet of thin-bedded, dark, cherty limestones; and, at the top, the "yellow limestone" which consists of some 650 feet of gray to yellow, massive limestone. The *Cibolocrinus* fauna, described by Weller,[4] was collected from the "lower brecciated zone."

Udden concluded that the Cieneguita and Alta formations are probably Pennsylvanian in age, and expressed the opinion that the Cibolo might be Permian.

In 1929, C. L. Baker[5] published a description of a series of lime-

[4] Stuart Weller, "Description of a Permian Crinoid Fauna from Texas," *Jour. Geol.*, Vol. 17 (1909), pp. 623–35.

[5] C. L. Baker, "Note on the Permian Chinati Series of West Texas," *Univ. Texas Bull. 2901* (1929), pp. 73–84.

stones, cherts, sandstones, and quartzites exposed near Ojo Bonito, several miles northwest of Udden's type section. Here, both the top and base of the section are covered by overlap or cut off by intrusives, and the exposure is not connected with the one described by Udden. Although he believed these beds to represent the upper Alta and lower Cibolo, Baker noted a marked difference in lithology from that exhibited in the type sections. Concerning this he says,

The transition beds of Udden apparently are not present in this section and the succeeding member, the lower brecciated zone, has changed greatly in lithology. Udden's lower brecciated zone consists of a grayish-white, heavy-bedded limestone, but in upper Cibolo basin, the member is mainly chert, blue, black, brown, and gray in color and only a minor amount of limestone in scattered thin beds, nodules, or concretions.

From the beds which he regarded as Cibolo, Baker collected such typical Word fossils as *Agathiceras girtyi* Böse, *Adrianites marathonensis* Böse, and *Stacheoceras gilliamense* Böse. From the underlying beds, which Baker called Alta, Robert E. King[6] collected *Dictyoclostus ivesi* (Newberry) and *Perrinites vidriensis* Böse. These last two fossils are characteristic of the Leonard formation of the Glass Mountains.

In this paper, Baker stated, "The characteristic lowermost Permian genus *Schwagerina* was found from bottom to top of the Cieneguita." Thus, he assigned the entire Chinati series to the Permian.

In this and a previous paper,[7] Baker briefly described a similar section in Pinto Canyon at the northwest end of the Chinati Mountains. Here, too, he believed he was dealing with lower Cibolo and upper Alta beds, and from the upper part of the exposure he obtained a Word fauna.

In 1935, C. P. Ross and W. E. Cartwright[8] described a series of Permian rocks exposed to the west of Shafter. About 1,100 feet of Paleozoic sediments crop out here, and the base of the section is overlapped by lava flows. At the top of the section there is about 100 feet of gray to yellow, dolomitic limestone, which is lithologically similar to the uppermost member of Udden's Cibolo. This is underlain by about 1,000 feet of dark gray, black, and red paper shales with occasional thin to heavy beds of dark gray to brown, cherty limestone. Ross and Cartwright tentatively correlated this section with a part of the Cibolo.

[6] R. E. King, "Geology of the Glass Mountains," Part II, *Univ. Texas Bull. 3042* (1930), p. 17.

[7] C. L. Baker, "Exploratory Geology of a Part of Southwestern Trans-Pecos Texas," *Univ. Texas Bull. 2745* (1927).

[8] C. P. Ross and W. E. Cartwright, "Preliminary Report on the Shafter Mining District, Presidio County, Texas," *Univ. Texas Bull. 3401* (1935), pp. 573–608.

STATIGRAPHY AND CORRELATION

In May, 1937, and again in April and May, 1938, the writer visited the Chinati Mountains and examined all the principal Paleozoic

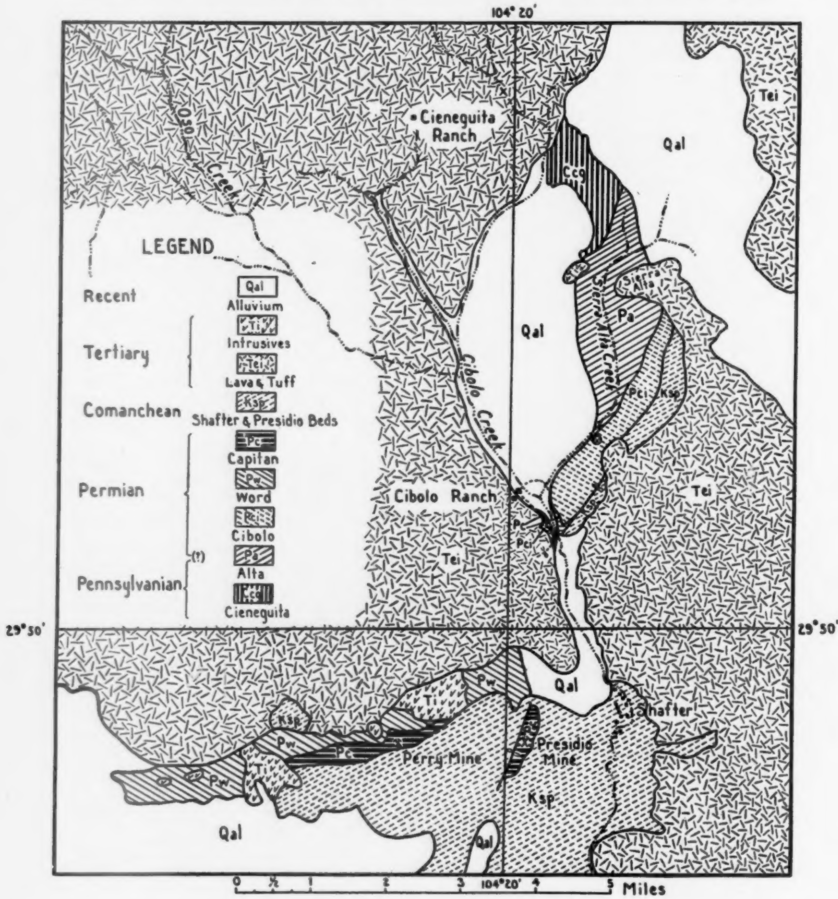

FIG. 2.—Areal map of Shafter region.

exposures with the exception of the one near Ojo Bonito. Many fossils were collected and identified, and correlations were made on the basis of these faunas. The results of this work can best be shown by considering the exposures separately.

BEDS EXPOSED NORTH OF SHAFTER IN VICINITY OF SIERRA ALTA

This section is the one selected by Udden as the type of all three of his formations, and, as such, is the one on which stratigraphic definition of these units must be based. Also, determinations of age made from study of this section are not qualified by questions of intercorrelation of local sections.

The Cieneguita is typically exposed northwest of Sierra Alta (Fig. 2) along the road leading from the Shafter-Marfa highway to Cieneguita Ranch. There can be no doubt that this is Udden's type locality for the formation, since it may be seen to underlie the type Alta and since it answers both the lithologic and geographic descriptions given by Udden. This is also nearer to Cieneguita Ranch, from which the formation name is derived, than any other sedimentary exposure. The formation contains a number of fossiliferous limestones scattered through the section. One of these, about 200 feet above the base of the exposure, carries numerous individuals of two or more undescribed species of *Fusulina* ss. Since this genus is not known to range above the East Mountain shale of north-central Texas or above the Des Moines series of the Mid-Continent region, the lower part of the Cieneguita may be regarded as Strawn in age. In the limestones of the upper half of the formation, numerous specimens of a new species of *Triticites* were found. The evolutionary development of this form is such that it is believed to be middle or upper Canyon in age. This would correspond roughly with the upper Missouri and lower Virgil series of the Mid-Continent area. The contact with the overlying Alta is not sharp but appears to be gradational. The change consists of an upward increase in sandstone and shale and a decrease in limestone. The shale between the two uppermost Cieneguita limestones is very similar, lithologically, to the shales of the Alta. The writer has arbitrarily drawn the contact at the base of a heavy sandstone some fifty feet above the highest Cieneguita limestone.

The Alta of the type section has yielded no fossils other than a few brachiopod spines and crinoid stems.

The Cibolo, however, was found to be very fossiliferous. From the "transition beds" of Udden, a fine assemblage of upper Wolfcamp fusulinids was obtained including *Schwagerina linearis* Dunbar and Skinner, *Schwagerina diversiformis* Dunbar and Skinner, *Schwagerina huecoensis* Dunbar and Skinner, *Pseudoschwagerina uddeni* Beede and Kniker, and *Pseudoschwagerina texana* Dunbar and Skinner. Two of these species, *S. linearis* and *S. diversiformis,* continue to within about 50 feet of the top of the Cibolo. All of these forms, with the exception of *S. linearis,* occur elsewhere throughout the upper

two thirds of the lower Permian Wolfcamp. *S. linearis* has been found only in the upper part of that formation. Since none of these species is known to continue into the overlying Leonard formation, all except the uppermost part of the Cibolo of Udden must be regarded as upper Wolfcamp in age. Of this uppermost portion, which Udden included in his "yellow limestone" member, approximately 50 feet is exposed. It is, however, red in color rather than yellow, and contains the brachiopod genus *Leptodus*. Since this genus is not known to occur in beds older than the Leonard formation of the Glass

FIG. 3.—Massive Cibolo limestone (*Pci*) overthrust on thin-bedded limestone of Capitan age (*Pc*) in east bluff of Cibolo Creek about ½ mile southeast of Cibolo Ranch house.

Mountains, and since the fusulinids found in the red limestone belong to the genus *Schwagerina* which is not known to occur above the middle Leonard, this zone must be regarded as lower Leonard in age. In view of the transitional character of the Alta-Cibolo contact, the writer believes that the upper part of the Alta is of lower Wolfcamp age. However, since the Alta is apparently conformable on beds of Canyon age, it is possible that the lower part of the formation is upper Pennsylvanian in age. If this is true, the Alta would occupy a position analogous to that of the Cisco group of north-central Texas, as the Cisco was originally defined.

An interesting feature of the type section of the Cibolo is the superposition of its upper member, by overthrusting, upon thin-bedded limestones of upper Permian (Capitan) age. This overthrust is very well exposed in the bluffs of Cibolo Creek (Fig. 3) a short

distance south of its confluence with Sierra Alta Creek. Although Udden does not mention this overthrust, it is hardly possible that he failed to see it, since this exposure is a part of his type locality. The most plausible explanation of his failure to speak of it is to assume that he believed the limestone of Capitan age to be a part of his "thin-bedded" member, and therefore supposed the fault to be a normal one of minor importance. The thrust plane is very irregular and the dip varies, but in general it is very low. However, since the beds are steeply tilted, the fault cuts them at a rather high angle. A normal fault crosses the strike of the overthrust at a low angle and drops the Comanche beds into contact with both the Cibolo and the Capitan at the south end of the exposure. Due to this circumstance and to the subsequent blanketing of the area by lava flows, it is impossible, from information now available, to determine definitely the age of the overthrust. It is possible, however, that future detailed work in the area may supply the answer to this question.

The ammonoid *Cibolites uddeni* Plummer and Scott was first discovered at this locality. Since it is known elsewhere only in the Capitan equivalents in the Delaware Mountains, it is probable that the original specimen was obtained from the limestone of Capitan age exposed here.

BEDS EXPOSED WEST OF SHAFTER

Permian rocks crop out in a narrow band extending from 1–6 miles west of Shafter. They are perhaps best exposed in the vicinity of the Perry mine, where Ross and Cartwright measured their section. From the yellow, dolomitic limestone at the top of this section, *Polydiexodina shumardi*, Dunbar and Skinner, *Codonofusiella paradoxica* Dunbar and Skinner, and *Leëla bellula* Dunbar and Skinner were obtained. These fossils are known only from beds of upper Permian (Capitan) age, and demonstrate conclusively that this bed is not the upper yellow limestone of Udden's Cibolo limestone. This same bed is brought to the surface by faulting in the vicinity of the Presidio mine, and from it most of the silver produced in the area has been obtained.

From limestones at intervals throughout the underlying section numerous middle Permian fusulinids, such as *Parafusulina bösei* Dunbar and Skinner and *Parafusulina sellardsi* Dunbar and Skinner were collected. These species are found in the Word formation of the Glass Mountains and are not known to range above or below that formation. Consequently, the entire section exposed west of Shafter must be regarded as younger than Cibolo.

Pinto Canyon Section

At the northwest end of the Chinati Mountains, in Pinto Canyon, approximately 850 feet of Permian sediments are exposed in an anticline, the west limb of which has been faulted. The highest beds exposed consist of about 450 feet of heavy to thin-bedded dark limestones with interbedded black shales and bedded chert. These limestones yielded numerous Word fusulinids and probably correlate with the basal portion of the Perry mine section, and with a part of the Word in Baker's Ojo Bonito section. Underlying the Word limestone beds is a succession of approximately 400 feet of gray, yellow, and brown, thin-bedded sandstone and sandy shale in which no fossils were found. However, the position of this group beneath the Word limestone and its resemblance to the *Perrinites*-bearing beds of the Ojo Bonito section strongly suggest that it is Leonard in age.

SUMMARY

The Chinati Mountain Paleozoic section appears to consist of a fairly representative sequence of Pennsylvanian beds and a nearly complete Glass Mountain Permian section. All of the Glass Mountain Permian formations are represented, at least in part, and the total thickness of the Chinati Permian apparently is not less than 6,800 feet.

It will be seen, from the foregoing remarks, that Udden's original conclusions as to the age of his Chinati series were very nearly correct—much more so, in fact, than later correlations based on fossils collected from exposures other than the type locality. The principal cause of the confusion, of course, is the remarkable lithologic resemblance of the Leonard to the Alta and the Word to the Cibolo.

Although, because of their long standing, Udden's formational names are retained, no local names are proposed for the Leonard, Word, and Capitan of the Chinati Mountains, for the writer thinks that the literature of the West Texas Permian is already encumbered with an overabundance of local names for identical formations.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 1 (JANUARY, 1940), PP. 189-190

REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library and available to members and associates.

RECENT PUBLICATIONS

ALASKA

"Areal Geology of Alaska," by P. S. Smith. *U. S. Geol. Survey Prof. Paper 192* (1939). Supt. Documents, Govt. Printing Office, Washington, D. C. 100 pp., 18 pls. Price, $1.25.

ARKANSAS

*"Data on Gas-Driven Pool Disclose Characteristics Differing from Water-Driven Reservoirs," by Alec M. Crowell. *Petrol. Engineer*, Vol. 11, No. 1 (Dallas, Texas, October, 1939), pp. 25–30; 8 figs., 4 tables. "Complete production data since discovery of gas-driven pool in Schuler field, Arkansas, will be a valuable case-record for the petroleum industry."

*"Development and Early Exploitation of a Water-Driven Oil Pool under Proration," by Alec M. Crowell. *Ibid.*, Vol. 11, No. 2 (November, 1939), pp. 21–26; 3 figs., 4 tables, 1 photograph, 1 stratigraphic column. "Data on Magnolia field, Arkansas, indicate water drive may result in reservoir pressure being maintained at near original figure."

CALIFORNIA

*"Tie-Ins between the Marine and Continental Records in California," by J. Edmund Eaton. *Amer. Jour. Sci.*, Vol. 237, No. 12 (New Haven, Connecticut, December, 1939), pp. 899–919; 2 figs.

CANADA

*"Paleontology and Stratigraphy of the Silurian Rocks of the Port Daniel-Black Cape Region, Gaspé," by Stuart Alvord Northrop. *Geol. Soc. America Spec. Paper 21* (New York, November 30, 1939). 302 pp., 28 pls., 1 fig.

GENERAL

**Report of the Committee on Sedimentation, 1938–1939*, by Parker D. Trask *et al.* National Research Council, Washington, D. C. (September, 1939). 102 mim. pp. 8.25×10.625 inches. Paper cover. Free, except $0.15 *in stamps*.

"Bureau of Mines-A. P. I. Pressure Core Barrel (Progress Report on Its Design and Development)," by D. B. Taliaferro and R. E. Heithecker. *U. S. Bur. Mines Rept. Investig. 3481* (November, 1939). 19 mim. pp. Free.

*"Secondary Recovery of Petroleum," Pt. 1—Bibliography, by John I. Moore. *Univ. Kansas State Geol. Survey Bull. 25* (Lawrence, Kansas, November 1, 1939). 103 pp.

*"Review of Cutler's Rule of Well Spacing," by H. C. Miller and R. V. Higgins. *U. S. Bur. Mines R. I. 3479* (Washington, D. C., November, 1939). 23 mim. pp., 1 fig., 1 table.

ILLINOIS

Oil and Gas Development Map of McLeanboro Area (Ts. 4–6 S., Rs. 6–8 E.), price, $0.60; *Mt. Carmel* (Ts. 1–3 S., Rs. 12–13 W.), price, $0.40; *Nashville* (Ts. 1–3 S., Rs. 2–4 W.), price $0.60. *Illinois Geol. Survey.* Scale, 2 inches = 1 mile. Blue prints obtainable from map agent, 305 Ceramics Building, Urbana.

KANSAS

*"Relation of Thickness of Mississippian Limestones in Central and Eastern Kansas to Oil and Gas Deposits," by Wallace Lee. *Univ. Kansas State Geol. Survey Bull. 26* (Lawrence, Kansas, June 15, 1939). 42 pp., 4 figs., 3 pls.

*"Western Kansas Oil and Gas Developments during 1938," by Walter A. Ver Wiebe. *Ibid., Min. Resources Cir. 13* (April 15, 1939). 106 pp., illus.

*"Oil and Gas Seeps in Smith County, Kansas," by Kenneth K. Landes and John M. Jewett. *Ibid., Cir. 12* (May 1, 1939). 10 pp., 1 fig.

MISSISSIPPI

*"The Alamucha Structure." *Mississippi State Geol. Survey Press Mem.* (December 4, 1939). 2 mim. pp. and a map of this structure in Lauderdale County.

MONTANA

"The Coal Resources of McCone County, Montana," by A. J. Collier and M. M. Knechtel. *U. S. Geol. Survey Bull. 95* (1939). 80 pp., 16 pls., 49 figs. Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $0.75.

NORTH CAROLINA

"Foraminifera, Diatoms, and Mollusks from Test Wells near Elizabeth City, North Carolina," by L. G. Henbest, K. E. Lohman, and W. C. Mansfield. *U. S. Geol. Survey Prof. Paper 189-G* (1939), pp. 217–27, Figs. 28–29. Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $0.10.

NORTH DAKOTA

"Geology and Coal Resources of the Minot Region, North Dakota," by D. A. Andrews. *U. S. Geol. Survey Bull. 906-B* (1939), pp. 43–84, Pls. 11–15, Figs. 11–17. Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $0.50.

WYOMING

*"Shoshone Anticline, Park County, Wyoming," by W. G. Pierce. *U. S. Geol. Survey Press Notice 78988* (November 18, 1939). 5 mim. pp., structure-contour map and cross sections.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

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COMMITTEE STUDYING METHODS OF ELECTING OFFICERS

WALTER R. BERGER, *chairman*, Trinity Building, Fort Worth, Texas

R. M. BARNES — A. R. DENISON — C. E. DOBBIN

OCCUPATIONAL SURVEY OF MEMBERSHIP

The Executive Committee believes that an occupational survey of our membership is desirable. Such a survey, never made heretofore, we believe will enable the Association and its committees better to appraise our policies and provide the membership with balanced Bulletin material. We are all more or less interested in what capacities we are engaged or employed a groups. A comprehensive survey of this nature should also have a guidance value to those about to enter the fields of applied geology. The survey form, which has been mailed to all members, we hope will be returned promptly to the Tulsa office for tabulation and an early Bulletin release.

The Executive Committee
HENRY A. LEY, Chairman

STUDENT AWARDS

The Executive Committee of the Association takes pleasure in officially approving and announcing the Student Award plan originated by the West Texas Geological Society, which plan is set forth in the following note. We are also pleased to learn that the South Texas Geological Society is adopting a similar plan of Student Awards, and sincerely hope that other affiliated geological societies will see fit to adopt similar plans rewarding outstanding students majoring in geology and/or allied professions.

In large measure the future of this Association rests upon the spontaneous interests of our younger members in Association affairs. The span of life is short. It is but a few years from Youth and initial Association membership to responsibilities as mature members and the call to committee or executive office. We are especially concerned with the rôle of Youth in this Association and measures that will recognize that rôle. We believe that needs recognized by local affiliated societies which are formulated by them and put into action by them are constructive and destined to be long enduring.

The Executive Committee believes that the national Association can further this admirable plan by:

(1) Recognizing the awards in our Bulletin. We believe that each year all recipients of awards should be set forth in one number of our Bulletin together with brief histories of the men and small photographs of each man, and

(2) the Association, through the Executive Committee, presents each award man with a complimentary copy of the latest Special Publication of the Association, or copies of the previous year's Bulletin.

The Executive Committee
HENRY A. LEY, Chairman

WEST TEXAS GEOLOGICAL SOCIETY
STUDENT AWARDS

The West Texas Geological Society, at a meeting July 21, 1939, considered and approved by resolution a Student Award Plan, presented by W. C. Fritz and Berte R. Haigh. The resolution provides for awards to

"promising" graduates of the geological departments of Texas Technological College at Lubbock, Texas, and the Texas College of Mines at El Paso, Texas; this award to consist of a two-year paid-up associate membership in the American Association of Petroleum Geologists.

A committee consisting of W. C. Fritz, Skelly Oil Company; John A. Hills, Amerada Petroleum Corporation; H. A. Hemphill, Magnolia Petroleum Corporation; and Berte R. Haigh, University Lands, was appointed by the President of the Society, under authority of a Society motion, to

(1) consult with the Executive Committee of the A.A.P.G.,
(2) develop the plan whereby the honorees are elected,
(3) consult with the schools to secure their permission and recommendations, and
(4) present the awards.

This committee, with Haigh as chairman, outlined a course of procedure. The West Texas Geological Society, thereupon, "earmarked" sufficient funds to guarantee the Plan for a period of at least five years. After conferences with the geological departments of the two schools, the committee adopted the following plan.

Immediately following the fall semester final examinations (normally held during the last week in January) a committee (which at Texas Technological College will consist of three members of the Geological Department Faculty and three students of Junior or Senior standing and which at Texas College of Mines will consist of the Dean of Mining and Metallurgy, two members of the Geological Department Faculty and two students of Junior standing) will select the honoree from among those undergraduate students with Senior standing on a five-point basis: grades, general ability, initiative, personality, and quality as A.A.P.G. membership material. The selected honoree will be certified as such to the West Texas Geological Society and his application for Associate Membership in the Association, properly executed and signed by the honoree, will be forwarded by the West Texas Geological Society, with its official recommendation, to the Executive Committee of the A.A.P.G. for action according to the constitution and by-laws of the Association. Upon approval of the application and election of the honoree to membership his dues will be paid by the West Texas Geological Society and his membership card and code of ethics will be presented to him by a representative of the W.T.G.S. at his graduation exercises the following June.

Student members of the Selection Committee representing Texas Tech will consist of one member of Sigma Gamma Epsilon, one member from the student Petroleum Engineering Society and one geological student who is not a member of either society. The student members of this committee at College of Mines will be the Junior Academic and Engineering Representatives in the student assembly.

REPORTS OF COMMITTEE STUDYING METHODS OF ELECTING OFFICERS

Fort Worth, Texas
November 29, 1939

Executive Committee
American Association of Petroleum Geologists

Henry A. Ley, President
L. Murray Neumann, Vice-President
Ed. W. Owen, Secretary
W. A. Ver Wiebe, Editor

Gentlemen:

As instructed by letter of June 9, 1939, the Committee on Methods of Electing Officers has made a thorough study of the different methods of election of officers.

The investigation and study, by your committee, covered the following:

1. Complete study of the Association files of the two previous Committees on Methods of Election (1928 and 1930).
2. Personal contact with members.

3. Correspondence with members with the purpose of obtaining individual opinions concerning the type of changes considered advisable. This correspondence requested the personal opinions of the Past-Presidents, the Presidents of Sections and Affiliated Societies, and those members showing particular interest in changing the method of election in the two previous studies.
4. A majority of the committee was present at a conference held in East St. Louis September 1, 1939.
5. Extensive correspondence between members of the committee.

The correspondence and personal contact presented many different plans varying from slight to radical changes in our present method of election. These proposals included plans similar to those now in use by other large organizations.

Tabulation of the answers to correspondence requesting personal opinions showed the following percentage in favor of retention of present method of election:

Past-Presidents—15 answers—53.3%.

Presidents of Sections and Affiliated Societies—14 answers to 25 requests—35.7%. However, assuming that unanswered letters showed lack of interest toward a change, the percentage would increase to 64%.

Members showing particular interest in previous studies—10 answers to 14 requests—all still in favor of a change.

No record was kept of personal contacts but it is assumed that the percentages would have been somewhat similar.

Your committee is submitting herewith its report divided into two parts: a Majority Report prepared by R. M. Barnes, C. E. Dobbin, and W. R. Berger; and a Minority Report prepared by A. R. Denison.

Yours very truly,
W. R. Berger, Chairman

MAJORITY REPORT

COMMITTEE ON METHODS OF ELECTING OFFICERS

A Method of Electing Officers, in order to be as near perfect as possible should have certain objectives, the more important of which may be considered as the following:

1. Democratic.—In order to be democratic the largest possible percentage of the membership should be represented in the election.
2. Non-cumbersome.—The degree of cumbersomeness usually decides the life or duration of the particular method.
3. Interest.—Any method that causes loss of interest in the election may have distinct bearing on the entire organization.
4. Election of good officers.

The 15 different plans that have been submitted, including our present plan, fall into three main classes.

(a) Present plan of nomination and election at the annual meeting.
(b) Nomination by mail ballot with various methods of election.
(c) Election by mail ballot with various methods of nomination.

(a) Looking over the names of the past and present officers of our Association, there can be no question that our present plan of election has produced the type of men that have served well and have helped in making our organization what it is today. The plan has been democratic insofar as the members present have had the opportunity to vote; those present and not voting probably had too little interest to vote on any other method of election. The plan is certainly not cumbersome. The plan also has plenty of

interest, as shown by those years in which several candidates have been proposed. The main fault with our present plan is that many members are not present at the annual meeting. The second fault is that in numerous years only a single candidate for each office is presented, however this should be considered the fault of the membership as additional interest in elections would surely have brought forth more than one nomination for office.

(b and c) Theoretically mail ballots either in nomination or election should be successful in being democratic. However, as shown by the various organizations that are using one of these types of election methods, the loss of interest in a mail ballot is sufficiently large to permit only a portion of the ballots to be cast. To have your opportunity but not exercise your use of ballot may still be democratic but not successfully democratic. Apparently this could not be an improvement over our present method if no larger percentage of ballots are cast from our membership. Moreover any committees making nominations will be subject to criticism by some groups of members. The criticisms in other organizations having committee nominations appear to be more numerous than the criticism in our organization. A double ballot system of nomination and election would surely be too cumbersome to last. Apparently the more perfectly democratic the ballot system, the more cumbersome it becomes.

It is the opinion of the majority group of the Committee on Methods of Electing Officers that the present method being used comes closer to fulfilling the requirements of a successful method of election than any other method that has been proposed. We realize that this plan has certain criticisms, but a careful study of all of the other proposed plans suggests more serious criticisms than those that are present in the plan now being used.

It is the opinion of the majority group of the Committee on Methods of Electing Officers that our present method should be changed to permit the selection of Editor by the elected members of the Executive Committee.

Committee on Methods of Electing Officers
Members of Majority Group

W. R. Berger, *Chairman*
R. M. Barnes
C. E. Dobbin

MINORITY REPORT

COMMITTEE ON METHODS OF ELECTING OFFICERS

The following proposal for nomination and election of officers of The American Association of Petroleum Geologists is an effort to devise a plan to overcome some of the criticisms which have persistently been made of our present method. It does not fully satisfy the more common of these criticisms, namely, that too few of the membership have an opportunity to vote on the officers. It does allow the entire membership to express their opinion as to nominations. The chief change which this plan proposes is to place all nominations in the hands of the elected district representatives and requires more than one candidate to be chosen for each office, except that of editor. This plan is less simple than that now in use but should not prove too cumbersome to be workable. It is offered with the hope that interest will be stimulated in a renewed consideration of all features of our present method.

A PLAN FOR NOMINATING AND ELECTING OFFICERS FOR THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

1. The Business Manager will cause to be printed and will send to each full member of the Association, along with the statement of dues, a nomination card. On this card will be printed space wherein can be written the member's choice for one candidate for each of the following officers: President, Vice-President, Secretary-Treasurer. These cards must be returned to the headquarters office of the Association at least thirty days prior to the date of the annual convention. These cards need not be signed and a member need not pay his dues prior to indicating his choice for officers.

2. The Business Manager is required to tabulate and preserve these nomination cards and to keep them confidential for presentation to the Business Committee.

3. The Business Committee shall convene the day prior to the annual convention for the purpose of nominating officers for the Association. It shall select from its own group a chairman and secretary to serve during the nomination of officers. This Business Committee shall be composed only of those members elected by the districts and shall exclude members-at-large or others appointed to the Business Committee by the President.

4. The Business Committee shall receive the nomination cards and tabulation from the Business Manager of the Association and shall then, by secret or open voting, proceed to select *at least* two candidates for each of the offices of President, Vice-President, and Secretary-Treasurer from the names submitted on the nomination slips. More than two candidates may be selected for each of these offices if the Committee desires. They will also select one candidate for the office of Editor. It shall be the duty of this Business Committee to inquire into the availability and willingness of the several candidates to run. They shall not be required to select the two candidates for a respective office who have polled the highest number of votes on the nomination slips, but can use their best judgment in the selection of these candidates.

5. Candidates so selected by the Business Committee shall be submitted to the members, in good standing, who are in attendance at the meeting for balloting as is done under our present system of selecting officers.

6. The officers so selected shall take office at the close of the annual meeting, as under our present system.

Committee on Methods of Electing Officers
Member of Minority Group

A. R. DENISON

ASSOCIATION FINANCES

On January 1, 1939, the Association had a surplus of \$93,263.29* made up as follows:

Cash	\$ 14,224.22
Accounts Receivable	3,060.03
Stock of Publications	20,720.19
Miscellaneous	913.87
Investments*	63,177.72
Total Assets	\$102,096.03
Less liabilities and deferred income	8,832.74
Surplus	\$ 93,263.29

* In this analysis investments are carried at cost, and no allowance is made for fluctuations in their market value.

This surplus had accumulated as follows:

Year	*Net Income*	*Surplus**
Accumulated to Jan. 1, 1929		$42,809.79
1929	$ 9,281.06	52,090.85
1930	10,900.32	62,991.17
1931	7,171.52	70,162.69
1932	2,365.05	72,527.74
1933	2,768.93	75,296.67
1934	8,343.05	83,639.72
1935	925.60	84,565.32
1936	464.85	85,030.17
1937	4,481.28	89,511.45
1938	3,751.84	93,263.29

During the last four years, since the present scale of membership dues has been in effect, the total net income and consequent increase in surplus have amounted to only $9,623.57. During this same period that part of our income which was derived from investments has amounted to $9,673.77. Thus it is apparent that membership dues and all other sources of income except that from investments are barely sufficient to cover the operating expenses of the Association, and that the only additions now being made to our surplus come out of income derived from that surplus itself.

There has been some criticism of the policy of building up our surplus to its present size, with the argument that the Association was not intended to be a profit-making organization. Recently some sentiment has developed in favor of further reduction in dues. Your executive committee feels that the policies of our past officials have been far-sighted and have resulted in a current position that is enviably sound.

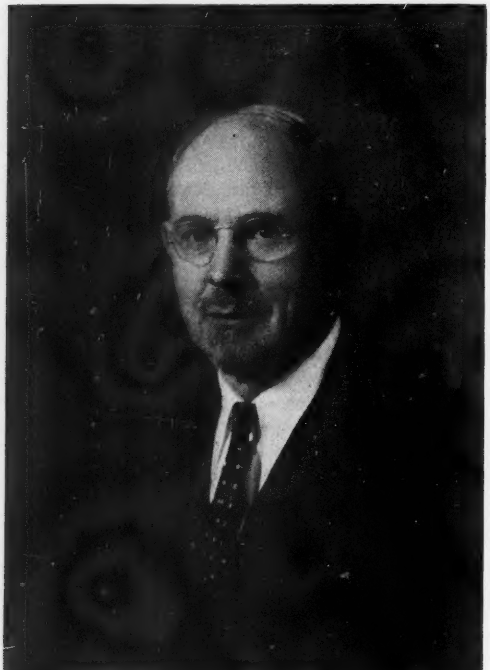
We believe that a surplus of the present magnitude is essential to insure the continuous operation of the Association on an efficient and useful plane. It is to be noted that the liquid part of our current assets is approximately equivalent to the gross operating expense for two years. A general inflation or a substantial increase in printing costs of the bulletin would require either an increase in dues, a contraction of our activities, or a call on our reserves. Any marked decrease in our membership which might result from a war, a major depression, or from fundamental changes which might occur in the nature of the oil business, would have a like effect. Our surplus, therefore, must be maintained in a sound, liquid condition, ready for use in any emergency, and not permitted to deteriorate into a pile of frozen assets. Probably its present magnitude is sufficient for the size of our organization. Certainly the problems of maintaining it unimpaired are of sufficient weight to tax the ability of your present officials.

The Executive Committee
By Ed. W. Owen
Secretary-Treasurer

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 1 (JANUARY, 1940), PP. 200-201, 1 FIG.

Memorial

WILLIAM ARTHUR TARR
(1881–1939)



WILLIAM ARTHUR TARR

Professor William Arthur Tarr was born March 29, 1881, in New Cambria, Missouri. He died at his home in Columbia, Missouri, July 28, 1939, after an illness of several months. He was married on April 30, 1905, to Miss Coralynn G. Neumann. He is survived by his wife, and by his parents and four brothers of Los Angeles, California.

Dr. Tarr's academic training was broad and thorough. In 1904, he received the degree of B.S. from Oklahoma A. and M. College; in 1908, the degree of B.S. in mining engineering from the University of Arizona, and, in 1916, the degree of Ph.D. from the University of Chicago. In 1927, in appreciation of the high rank he had attained in the scientific world because of his outstanding work in teaching and in scientific research, his first Alma Mater, Oklahoma A. and M. College, conferred upon him the honorary degree of Doctor of Science.

Dr. Tarr was engaged in educational work for many years. During 1908 and 1909, he was a member of the faculty at the University of Arizona. He was research assistant at the University of Chicago from 1909 to 1911. He came to the University of Missouri in 1911 as instructor in economic geology and mineralogy, and rapidly advanced to the rank of professor in charge of that phase of geological instruction.

During the school year, while busily engaged in teaching, he was just as busily conducting such research as time would permit and laying plans for study and research during the coming summer in, not one or two, but many phases of geology. If there was a particular phase of geological research in which he was more interested than any other, it was that which dealt with the origin of various earth materials. This accounts for some of his outstanding research dealing with the origin of chert, oölites, stylolites, detrital sediments, and some ore deposits. His published contributions to science are numerous. They include two text books and, in scientific journals, numerous papers dealing with ore deposits, mineralogy, and sedimentary rocks. He leaves in his laboratory many research projects only partially finished. Some of these, it is hoped, will be taken on to completion by his wife and co-worker, Coralynn G. Tarr.

Dr. Tarr was an active member of many organizations, including the American Association for the Advancement of Science, the Mineralogical Society of America, the Mineralogical Society of Great Britain and Ireland, the American Association of Petroleum Geologists, the Society of Economic Mineralogists, Sigma Xi, Gamma Alpha, Sigma Gamma Epsilon, of which he was national editor since 1920, Phi Kappa Phi, and Kappa Sigma.

During his 28 years at the University of Missouri, Dr. Tarr came in contact with hundreds of students. Some of them remember him as an active and popular member of the University Athletic Committee and the Men's Panhellenic Council. Others remember him through classroom association during one or more courses in geology as an instructor of outstanding ability. Those of us who knew him more intimately through association in the classroom, in the field, and in the research laboratory are most fortunate. We remember him as a great teacher in the classroom, who inspired us to continue the study of geology. In the field, we remember him as a keen observer with the faculty of seeing the various ramifications of the problems before him and then of setting to work tirelessly to collect the data necessary for their solution. We remember that often, when working on a field problem, he pointed out the opportunity for research to obtain essential or related data. Often the research problem, as foreseen by Dr. Tarr, developed into another problem of much broader scope, with corresponding difficulties; but he, though busy with numerous problems of his own, found time to give council, assistance, and inspiration so that the work might go on.

Personally, Dr. Tarr was a man of striking appearance and pleasing personality. He was a hard worker who expected interest and similar industry on the part of his co-workers, but was an interesting and inspiring companion at work. Yet, busy as he was, he and Mrs. Tarr found time for their recreational studies, the identifying and cataloging of a great many species of birds, flowers, and trees in the numerous localities where they have lived and worked.

RICHARD B. RUTLEDGE

TULSA, OKLAHOMA
November 27, 1939

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 1 (JANUARY, 1940), PP. 202-208

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

RALPH C. LORING is in the employ of the International Petroleum Company Ltd., Apartado 803, Guayaquil, Ecuador.

W. P. WOODRING studied the oil resources in the Santa Maria district, California, for the United States Geological Survey during the past summer.

D. A. ANDREWS has completed his fourth season of United States Survey work along the northeastern Bighorn Basin of Wyoming and Montana.

The National Geographic Society-University of Virginia southern Pacific expedition which was to have left San Francisco last September has been postponed because of different plans for the coastguard cutter *Hamilton*. Professor WILBUR A. NELSON, leader of the expedition, has resumed his geological work at the University of Virginia.

FREDERICK G. CLAPP, consulting geologist, 50 Church Street, New York, was working at Chickasha, Oklahoma, in November and December.

GEORGE B. SOMERS has gone to Egypt. His address is Socony-Vacuum Oil Company, Sharia Ibrahim Pasha, Cairo, Egypt.

FRANK A. OYSTER has moved his office for consulting geological work from Owensboro, Kentucky, to Evansville, Indiana.

A. A. BAKER has returned to Washington, D. C., following his summer field work for the United States Geological Survey in the southern Wasatch Mountains of Utah, studying oil and gas possibilities.

KATHLEEN KIRK, formerly of Tulsa, Oklahoma, is employed by the Superior Oil Company, Corpus Christi, Texas.

M. G. EDWARDS, recently district superintendent for the Shell Oil Company, is now manager of the Los Angeles division of the company at Long Beach, California.

IONEL I. GARDESCU and CARLETON D. SPEED, JR., have opened a consulting office in the Second National Bank Building, Houston, Texas.

T. A. HENDRICKS and PAUL AVERITT, of the United States Geological Survey, have returned to Washington, D. C., after investigating the geology and oil possibilities of the western Ouachita Mountains, Oklahoma.

JOHN V. TERRILL has resigned his position with the Gulf Oil Corporation at Amarillo and will be engaged in consulting geology at Midland, Texas.

J. M. CLAYTON, geologist with the Seaboard Oil Company at Dallas, spoke before the Houston Geological Society early in November on "Producing Formations above the Jackson in Southwest Texas."

F. A. Melton, of the University of Oklahoma, spoke before the Tulsa Geological Society on "Shore Processes as Revealed by Aerial Photographs," November 20.

John Henry Fackler, formerly with the Caracas Petroleum, S. A., is now in the employ of the Socony Vacuum Oil Company, S. A., at Caracas, Venezuela.

Eusebio Paulo de Oliveira, of the Geological Survey of Brazil, Rio De Janeiro, died on October 10, 1939.

Olin G. Bell, division production geologist of the Humble Oil and Refining Company, Houston, Texas, spoke on, "The Function of a Production Geologist," at a meeting of the Texas A. & M. College Student Chapter of the American Institute of Mining and Metallurgical Engineers, November 23 at College Station.

F. B. Plummer, of the University of Texas Bureau of Economic Geology, Austin, Texas, recently talked before the Shreveport Geological Society, Shreveport, Louisiana, on "The Geology and Structure of the Llano Uplift."

Edward J. Foley has accepted a position with the Standard Oil Company of Egypt, Sharia Kasr el Nil, No. 22, Cairo, Egypt.

Robert P. D. LaTouche, of the Standard Vacuum Oil Company, died at Banjermasin, Borneo, on September 15.

Clifford F. Barber, formerly with the United Producing Corporation at Beeville, is with the Forest Development Company at San Antonio, Texas.

A. I. Levorsen, past-president of the Association and chairman of the research committee, spoke before the Rocky Mountain Association of Petroleum Geologists at Denver, Colorado, November 20.

On November 24 the Panhandle Geological Society of Texas and the West Texas Geological Society held a joint dinner meeting with the department of geology and petroleum engineering of Texas Technological College on the college campus. Papers were given by John M. Hills, of the Amerada Petroleum Corporation, representing the West Texas Geological Society, on the subject, "Rhythms of the Permian Seas: A Paleogeographic Study," and G. L. Knight, of the Phillips Petroleum Company, representing the Panhandle Geological Society, on the subject, "Summary of the Geological History of the Panhandle of Texas." W. C. Fritz, of the Skelly Oil Company, representing the West Texas Geological Society, presented for study and discussion, "North-South Cross Section of South Permian Basin." Berte R. Haigh, president of the West Texas Geological Society, announced that the West Texas Geological Society would present at the June Commencement a 2-year paid-up membership in the American Association of Petroleum Geologists to the outstanding student in geology of the Senior Class of Texas Technological College and of the University of Texas School of Mines at El Paso. One hundred and forty-three persons attended the meeting, including representatives from the North Texas Geological Society and South Texas Geological Society.

CHARLES W. SEEDLE is employed by the Arkansas Fuel Oil Company at Shreveport, Louisiana.

ROBERT W. WILSON spoke before the Rocky Mountain Association of Petroleum Geologists at Boulder, Colorado, December 4, on the subject, "Quaternary Cave Faunas of the Southwestern United States."

JESS H. HENGST has resigned as chief geologist of the Continental Investment Corporation, Tulsa, Oklahoma, to become chief geologist of the Big Four Oil and Gas Company and the Southwestern Oil and Gas Company of Pittsburgh, Pennsylvania. His address is Box 396, Bridgeport, Illinois.

The Tulsa Geological Society presented a round-table discussion at Kendall Hall, University of Tulsa, December 4, on "Time of Accumulation of Oil in the Granite Ridge Pools with Special Reference to the Oklahoma City Pool." Leaders of the symposium were: IRA H. CRAM, of the Pure Oil Company; E. F. SHEA, of the Stanolind Oil and Gas Company; FREDERIC A. BUSH, of the Sinclair Prairie Oil Company (represented by STANLEY H. WHITE of the Ohio Oil Company); FRANK R. CLARK, of the Ohio Oil Company; and W. B. WILSON, of the Gulf Oil Corporation.

The Mississippi Geological Society met for the first time at a luncheon in the Edwards Hotel at Jackson, Mississippi, November 28, 1939, and elected the following officers: president, HENRY N. TOLER, Southern Natural Gas Company; vice-president, URBAN B. HUGHES, consulting geologist; secretary-treasurer, TOM MCGLOTHLIN, Gulf Refining Company of Louisiana. Meetings will be held on the first and third Tuesdays, each month, at 6:30 P.M. at the Edwards Hotel, Jackson, Mississippi. Members of the program committee are: PAT MEHOLIN, chairman, Sells Petroleum Company; D. C. HARRELL, Carter Oil Company; M. R. SARTAIN, consulting. Members of the membership and by-laws committee are: L. R. MCFARLAND, chairman, Magnolia Petroleum Company; ARTHUR WEDEL, Pure Oil Company; W. H. TAYLOR, Petty Geophysical Engineering Company. Thirty-eight members were present at the first meeting.

E. L. DEGOLYER, a past-president of the Association and a consulting geologist of Dallas and Houston, has been awarded the Anthony F. Lucas gold medal for 1940 by the American Institute of Mining and Metallurgical Engineers for distinguished achievement in improving the technique and practice of finding and producing petroleum. The University of Texas has added DeGolyer to its staff as a "distinguished professor."

JOHN R. SUMAN, vice-president of the Humble Oil and Refining Company, Houston, opened the Texas Personnel Conference at Austin, November 24 and 25, outlining essentials for an industrial relations policy.

The Midland Geological Society, Midland, Texas, has elected officers as follows: president, PRENTISS D. MOORE, Moore Brothers; vice-president, H. D. PENNEL, the Amerada Petroleum Corporation; secretary-treasurer, JOHN HARVEY HERD, the Standard Oil Company of Texas.

JOAN MARIE LARKIN, age 9, daughter of Mr. and Mrs. J. J. LARKIN, JR., 1432 South Denver Avenue, Tulsa, Oklahoma, died on November 19, 1939, after a month's illness.

H. HEMMINGS, recently with Bataafsche Petr. Mij., The Hague, may be addressed in care of the Shell Oil Company, Inc., 1008 West Sixth Street, Los Angeles, California.

LON D. CARTWRIGHT, JR., formerly division geologist for the Skelly Oil Company at Houston, is in charge of geological work for the Union Oil Company of California in the office recently opened at Houston, Texas. This office will handle activities for the Union Oil Company in Texas and adjacent states.

LESLIE BOWLING, formerly with the Tide Water Associated Oil Company, and WAYNE Z. BURKHEAD, formerly with the Superior Oil Company of California, are now with the Union Oil Company of California at Houston.

The East Texas Geological Society, Tyler, Texas, has elected the following officers for the ensuing year: president, E. M. RICE, the Pure Oil Company; vice-president, FRANK R. DENTON, the Stanolind Oil and Gas Company; secretary-treasurer, C. I. ALEXANDER, the Magnolia Petroleum Company.

ERNEST A. OBERING, of the geological department of the Shell Oil Company, Inc. has moved from Tulsa, Oklahoma, to Centralia, Illinois.

LINCOLN R. PAGE has left the department of geology at the University of Colorado, and is with the United States Geological Survey at Tinton, South Dakota.

SIDNEY E. MIX resigned as geologist for the Gulf Refining Company, Shreveport, Louisiana, effective December 1, 1939. He entered the services of the Gulf Production Company at Fort Worth, Texas, December 28, 1918, and was transferred to the Gulf Refining Company at Shreveport, February 9, 1919, and was in continuous service with the Gulf since that time. Mix has opened a consulting office in Shreveport. His home address is 902 Unadilla Street.

The North Texas Geological Society, Wichita Falls, has elected the following new officers: president, P. M. MARTIN, district geologist for the Continental Oil Company; vice-president, L. E. PATTERSON, Cities Service Oil Company; secretary-treasurer, R. E. MCPHAIL, Phillips Petroleum Company.

PAUL E. FITZGERALD, of Dowell Incorporated, Tulsa, Oklahoma, talked before the Panhandle Geological Society at Amarillo, Texas, November 2, on "New Developments in the Acidizing of Panhandle Wells."

PAUL WEAVER, of the Gulf Oil Corporation, Houston, Texas, talked on "Ground Water and Its Geological Interpretations," before the Shreveport Geological Society last November.

Progress of fundamental research on the occurrence and recovery of petroleum is outlined in quarterly reports of three research projects of the American Petroleum Institute, recently issued by C. A. YOUNG, secretary of the Institute's Division of Production, Dallas, Texas. The three projects, which, with others, are sponsored by the A.P.I. committee on research of the board of directors, are: Research Project No. 14, "Origin and Environment of

Source Sediments of Petroleum," directed by PARKER D. TRASK; Research Project No. 27, "Function of Water in the Production of Oil From Reservoirs," directed by F. E. BARTELL; and Research Project No. 37, "Fundamentals of the Retention of Oil by Sand," directed by W. N. LACEY.

The Western Kentucky Geological Society has elected officers as follows: president, PAUL F. OSBORNE, Tide Water Associated Oil Company; vice-president, EDWARD W. HARD, Sun Oil COMPANY; and secretary-treasurer, W. KEITH MILLER, Carter Oil Company; all of Evansville, Indiana. Executive committee members are: RALPH E. ESARY, Indiana Geological Survey, Bloomington, Indiana; KENNETH L. GOW, Superior Oil Company, Evansville, Indiana; and N. W. SHIARELLA, Miller & Shiarella, Owensboro, Kentucky, past president.

WITHERS CLAY, consulting geologist, formerly of Tulsa, and at Mt. Vernon, Illinois, since October, 1938, moved to Carmi, Illinois, November 1, to be closer to the Wabash valley play.

H. E. CHRISTLER, formerly with the Indian Oil Concessions, Karachi, India, is now with the Richmond Petroleum Company of Colombia, Apartado Nacional No. 3, Ibague, Colombia.

The Michigan Geological Society met at Michigan State College, December 6. Geophysical papers were presented by N. N. ZIRBEL, Independent Exploration Company, and W. S. KECK, Geophysical Department of Michigan State College. C. C. ADDISON, of the Pure Oil Company, Saginaw, is president, and R. P. GRANT, of the Michigan Geological Survey, Lansing, is secretary-treasurer of the society.

New officers of the Southwestern Geological Society at Austin, Texas, are: president, LEO HENDRICKS, Bureau of Economic Geology; vice-president G. M. STAFFORD, University of Texas department of geology; secretary-treasurer, S. A. LYNCH, University of Texas department of geology.

JOHN L. P. CAMPBELL is employed by the Marland Oil Company of Oklahoma at Ponca City.

F. G. CLAPP, consulting geologist, 50 Church Street, New York, spoke before the Tulsa Geological Society, December 18, on "Geologic Work and Experiences in the Middle East."

JOHN S. KELLOUGH, of the Schlumberger Corporation, spoke on "Electrical Exploration of Drill Holes" before the Rocky Mountain Association of Petroleum Geologists at Denver, December 18.

ROGER S. MAHONEY, of Wayne, Pennsylvania, may be addressed in care of the Mene Grande Oil Company, Barcelona, Anzoategui, Venezuela, S.A., Apartado 45.

The name of the Western Kentucky Geological Society has been renamed the Indiana-Kentucky Geological Society. PAUL F. OSBORNE, of the Tide Water Associated Oil Company is president and W. KEITH MILLER, of the Carter Oil Company, is secretary-treasurer, both of Evansville, Indiana. The program of December 8 included J. MARVIN WELLER, of the Illinois

Geological Survey, C. A. MALOTT, of the Indiana State University, and D. J. JONES, State Geologist of Kentucky, in a discussion of "The Chester-Ste. Genevieve Outcrops Nomenclature." Sixty-two geologists were in attendance. A study group was formed to study problems resulting from confusion of correlations between wells of the three states and between "Basin" wells and the outcrop stratigraphy.

KARL POBST has returned to Tulsa, Oklahoma after more than a year in the service of Yacimientos Petroliferos Fiscales, Buenos Aires, Argentina.

M. M. KORNFELD, Houston consulting geologist, was guest speaker at the December meeting of the South Louisiana Geological Society at Lake Charles December 12. His topic was "The Relation of the Hackberry Zone to Oil and Gas Accumulation in the Gulf Coast."

THERON WASSON, chief geologist of the Pure Oil Company, talked before the Chicago Section of the A.I.M.E. at the Chicago Engineers' Club, January 10, on "New Developments in the Exploration for Petroleum."

The annual meeting of the A.I.M.E. will be held in New York City February 12–15.

The annual meeting of the Canadian Institute of Mining and Metallurgy will be held at Winnipeg, March 11–13.

The American Chemical Society will meet in Cincinnati, Ohio, April 8–12.

The International Petroleum Exposition, Tulsa, Oklahoma, will be held on May 18–25.

The mid-year meeting of the American Petroleum Institute will be held at Fort Worth, Texas, May 27–31.

PAUL E. FITZGERALD, geologist with Dowell, Incorporated, Tulsa, has been appointed chairman of the International Petroleum Exposition committee on exploration for the 1940 show, May 18–25.

TWENTY-FIFTH ANNUAL MEETING, CHICAGO, APRIL 10–12, 1940

COMMITTEE CHAIRMAN APPOINTED

General Chairman

VERNER JONES, president, Illinois Geological Society
Address: Magnolia Petroleum Company, Mattoon, Illinois

Technical Program

A. H. BELL, A.A.P.G. Great Lakes District representative
Address: Illinois Geological Survey, Urbana, Illinois

Arrangements

J. V. HOWELL, consulting geologist, Mt. Vernon, Illinois

Trips

M. M. LEIGHTON, chief, Illinois Geological Survey Division
Address: 305 Ceramics Building, Urbana, Illinois

Finance

E. W. ELLSWORTH, secretary-treasurer, Illinois Geological Society
Address: W. C. McBride, Inc., Centralia, Illinois

Chairman Bell reports that the technical program, which is to be held in the Grand Ballroom of the Stevens Hotel, is tentatively arranged in six half-day sessions as follows.

April, 10. Wednesday
Morning: General session. Chairman, HENRY A. LEY
Afternoon: Program by research committee. Chairman, A. I. LEVORSEN

April 11. Thursday
Morning: Eastern Interior basin
Afternoon: Michigan and Appalachian basins

April 12. Friday
Morning: Mid-Continent and Rocky Mountain regions
Afternoon: Gulf Coast and California regions

The following subchairmen have been appointed on the technical program committee.

Region	*Subchairman*
Eastern Interior basin	M. W. Fuller, Box 568, Mattoon, Illinois
Michigan basin	R. B. Newcombe, 901 Otillia, SE., Grand Rapids, Michigan
Appalachian basin	M. G. Gulley, Box 1166, Pittsburgh, Pennsylvania
Mid-Continent	Ira H. Cram, Box 271, Tulsa, Oklahoma
Rocky Mountains	C. E. Dobbin, 224 Custom House, Denver, Colorado
Gulf Coast	K. H. Crandall, Box 1249, Houston, Texas
Pacific Coast	E. R. Atwill, Union Oil Company, Los Angeles, California

It is proposed that the program on each region be introduced by a paper pointing out the significant developments during the previous year. This will be followed by a series of papers on petroleum geology in the region. Each subchairman will be responsible for the general make-up of the program on his region.

In addition to the oral presentation of papers that will emphasize the outstanding developments, it is recommended that more detailed and comprehensive papers on each region or subdivision thereof be prepared at the same time for publication in the *Bulletin*.

Authors are referred to the Association's leaflet *Preparation of Manuscripts*, copies of which are available from Association headquarters, Box 979, Tulsa, Oklahoma.

DEADLINE DATES

Authors who wish to present papers at the Chicago convention are asked to communicate at once with their regional subchairman giving titles of proposed papers. In order that titles and abstracts of papers may be included in the printed program it is necessary that they be in chairman Bell's hands by March 1, 1940. However, they should all pass through the hands of the regional subchairman, and *duplicate copies* should be sent so as to reach him by February 20. The regional subchairman should then determine the sequence of papers for the program and submit the list of papers, the time allotted each for presentation and discussion, and one set of abstracts by March 1.

OKLAHOMA

ELFRED BECK
Geologist

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TULSA, OKLA.

1222-A Republic Natl.
Bank Bldg.
DALLAS, TEX.

GINTER LABORATORY
CORE ANALYSES
Permeability
Porosity
Reserves

R. L. GINTER
Owner

118 West Cameron, Tulsa

MALVIN G. HOFFMAN
Geologist

Midco Oil Corporation
Midco Building
TULSA, OKLAHOMA

R. W. Laughlin L. D. Simmons

WELL ELEVATIONS

LAUGHLIN-SIMMONS & CO.
615 Oklahoma Building
TULSA OKLAHOMA

A. I. LEVORSEN
Petroleum Geologist

221 Woodward Boulevard
TULSA OKLAHOMA

GEO. C. MATSON
Geologist

Philcade Building TULSA, OKLA.

G. H. WESTBY
Geologist and Geophysicist
Seismograph Service Corporation

Kennedy Building Tulsa, Oklahoma

PENNSYLVANIA

HUNTLEY & HUNTLEY
Petroleum Geologists
and Engineers

L. G. HUNTLEY
J. R. WYLIE, JR.
Grant Building, Pittsburgh, Pa.

TEXAS

JOSEPH L. ADLER
Geologist and Geophysicist

Consultant and Contractor in Geological and Geophysical Exploration

325 Esperson Bldg.
HOUSTON, TEXAS

MID-CONTINENT TORSION BALANCE SURVEYS
SEISMIC AND GRAVITY INTERPRETATIONS

KLAUS EXPLORATION COMPANY
H. KLAUS
Geologist and Geophysicist

115 South Jackson
Enid, Oklahoma

2223 15th Street
Lubbock, Texas

TEXAS

FORT WORTH GEOLOGICAL SOCIETY
FORT WORTH, TEXAS

President - - - - - - J. Earle Brown
Consulting Geologist, Trinity Life Building

Vice-President - - - - - J. H. Markley
The Texas Company

Secretary-Treasurer - - - - Vernon Lipscomb
The Pure Oil Company

Meetings: Luncheon at noon, Worth Hotel, every Monday. Special meetings called by executive committee. Visiting geologists are welcome to all meetings.

NORTH TEXAS GEOLOGICAL SOCIETY
WICHITA FALLS, TEXAS

President - - - - - - - - - P. M. Martin
Continental Oil Company

Vice-President - - - - - - L. Edwin Patterson
Cities Service Oil Company

Secretary-Treasurer - - - - - R. E. McPhail
Phillips Petroleum Company

Luncheons and evening programs will be announced.

SOUTHWESTERN GEOLOGICAL SOCIETY
AUSTIN, TEXAS

President - - - - - - - - Leo Hendricks
Bureau of Economic Geology

Vice-President - - - - - - - - G. M. Stafford
Univ. Texas., Dept. of Geology

Secretary-Treasurer - - - - - - - S. A. Lynch
Univ. Texas, Dept. of Geology

Meetings: Every third Friday at 8:00 P.M. at the University of Texas, Geology Building 14.

WEST VIRGINIA

THE APPALACHIAN GEOLOGICAL SOCIETY
CHARLESTON, WEST VIRGINIA
P.O. Box 1435

President - - - - - - Robert C. Lafferty
Owens, Libbey-Owens Gas Department

Vice-President - - - - - - J. R. Lockett
Ohio Fuel Gas Company
Columbus, Ohio

Secretary-Treasurer - - - - Charles Brewer, Jr.
Godfrey L. Cabot, Inc., Box 348

Meetings: Second Monday, each month, at 6:30 P.M., Kanawha Hotel.

HOUSTON GEOLOGICAL SOCIETY
HOUSTON, TEXAS

President - - - - - - Wallace C. Thompson
General Crude Oil Company

Vice-President - - - - Carleton D. Speed, Jr.
Speed Oil Company

Secretary - - - - - - - - - - Olin G. Bell
Humble Oil and Refining Company

Treasurer - - - - - - - - - - A. P. Allison
Sun Oil Company

Regular meeting held every Thursday at noon (12 o'clock) above Kelly's Restaurant, 910 Texas Avenue. For any particulars pertaining to the meetings write of call the secretary.

SOUTH TEXAS GEOLOGICAL SOCIETY
SAN ANTONIO AND CORPUS CHRISTI
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President . . . . - Willis Storm
1733 Milam Building, San Antonio

Vice-President - - - - - - - Dale L. Benson
Sinclair Prairie Oil Company, Corpus Christi

Secretary-Treasurer - - - - Robert N. Kolm
1742 Milam Building, San Antonio

Executive Committee - - - - - E. L. Porch

Meetings: Third Friday of each month at 8 P.M. at the Petroleum Club. Luncheons every Monday noon at Petroleum Club, Alamo National Building, San Antonio, and at Plaza Hotel, Corpus Christi.

WEST TEXAS GEOLOGICAL SOCIETY
MIDLAND, TEXAS

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University Lands

Vice-President - - - - - - - - - W. C. Fritz
Skelly Oil Company

Secretary-Treasurer - - - - - J. E. Simmons
Continental Oil Company

Meetings will be announced

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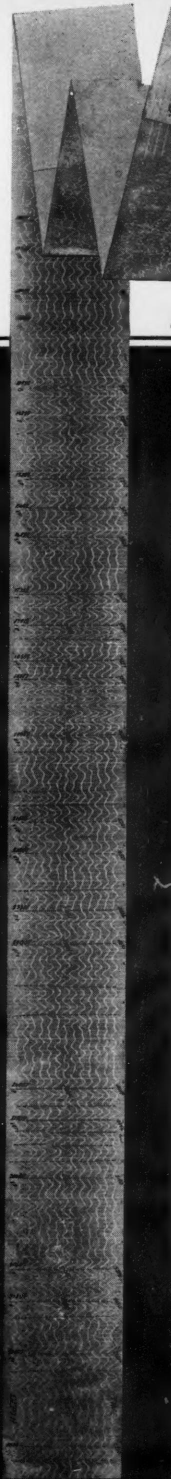

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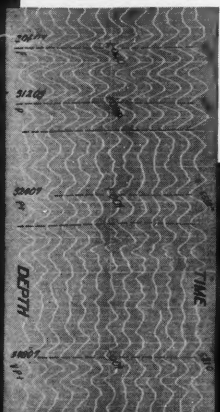

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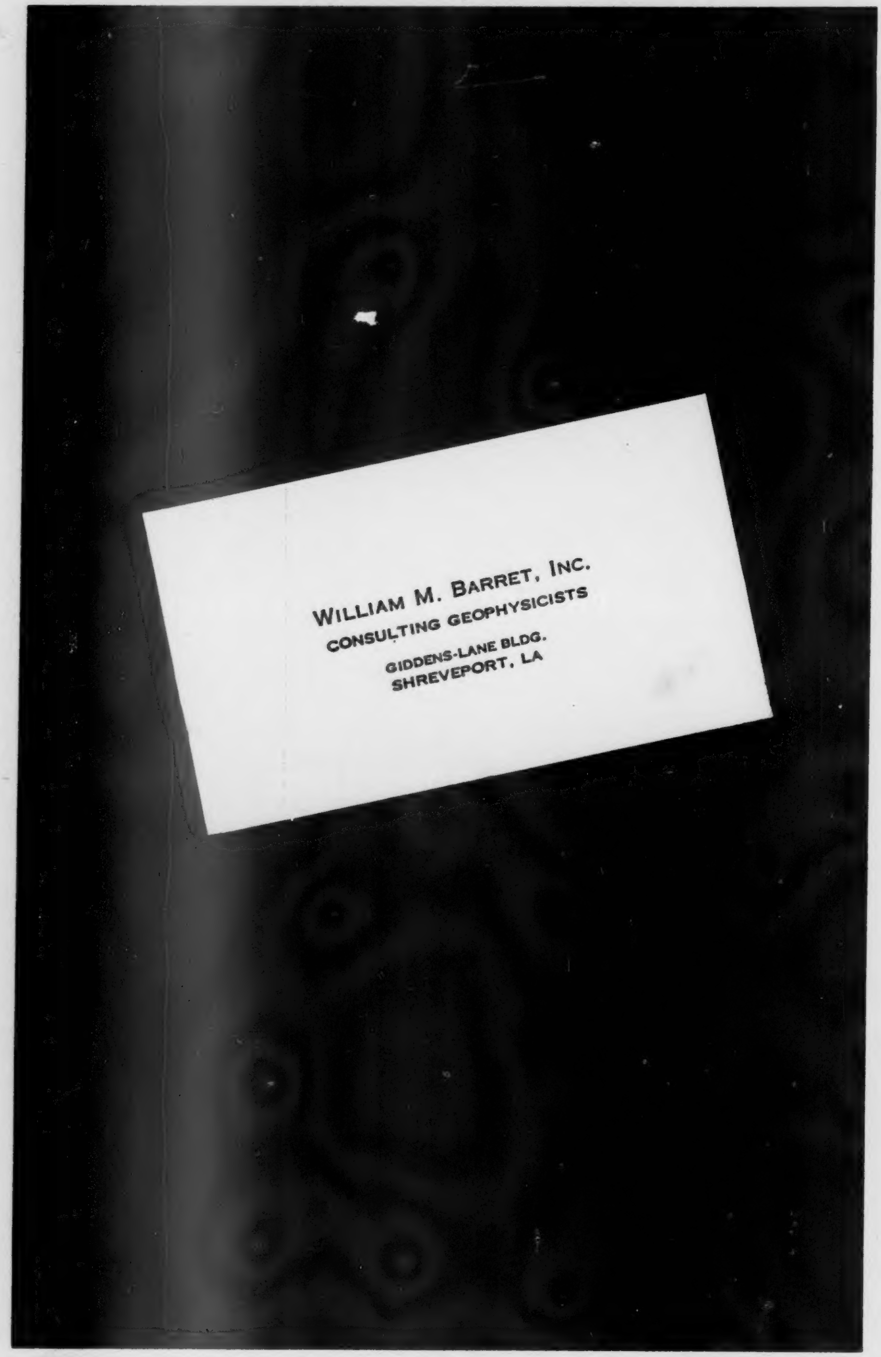
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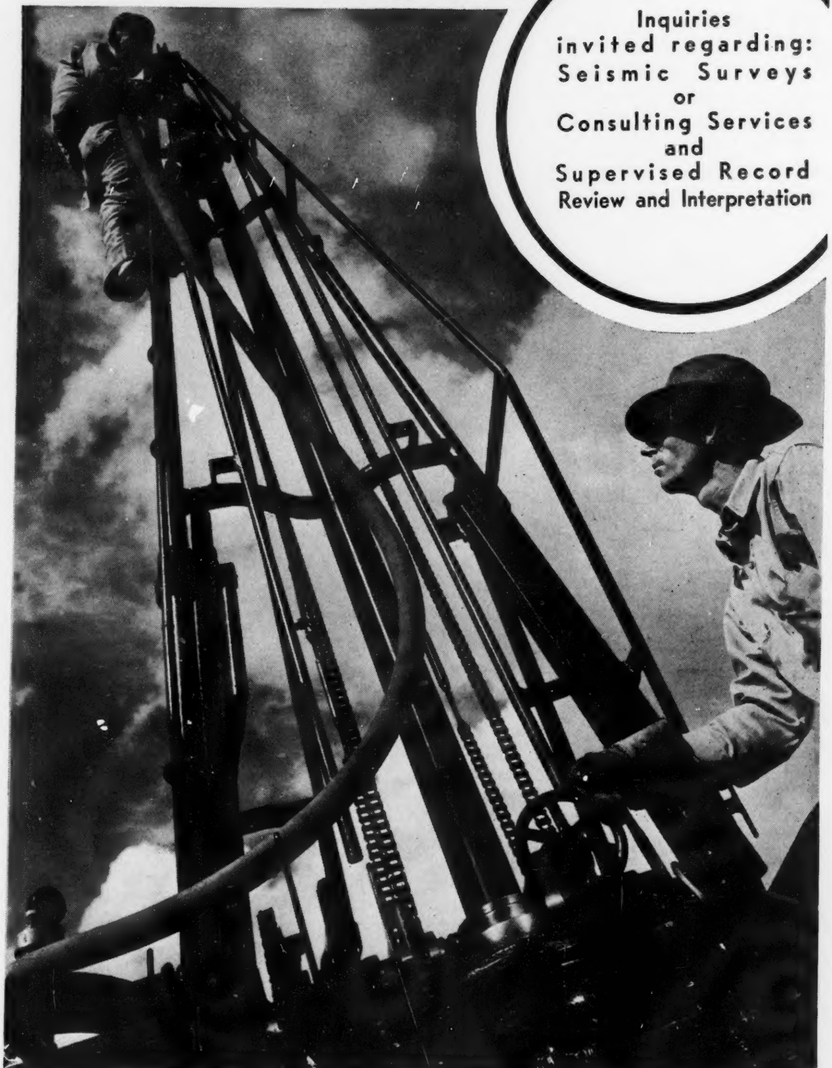


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